

SPEED-TIME CURVE STUDY
OF
ELECTRIC RAILWAY LOAD CONDITIONS

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SPEED-TIME CURVE STUDY
OF
ELECTRIC RAILWAY LOAD CONDITIONS

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I N T R O D U C T I O N

INTRODUCTION.

The shapes of the several load-curves of sub-stations and power-plants play important roles in the economics of the design and operation of such plants; in fact, the economics of the design depend equally on the shapes of the load-curves and cost of material. Hence the proper estimation of the probable load-curves which will accompany certain operating conditions is a matter of great importance.

In the design of plant for an Electric Railway many things influence the future load-curves of its power plant and sub-stations. The weight of each car, the size of each equipment, its characteristics, the distance between sub-stations, the distribution of feeder material between sub-stations, the frequency of train service, the number of car units per train, the number, placing, and

timing of train stops, the shape of the schedule sheet, and many other factors influence the sub-station load-curves. These, and the number of sub-stations fed by one power-plant influence the power-plant load-curves.

The importance of each of these factors depends largely upon the nature of the system considered, and in many cases some of these factors are deemed of too little importance to demand attention. In other cases each factor is of sufficient economic importance to warrant its careful consideration. Thus, in the case of an elevated line or an electrified steam suburban line the handling of the morning and evening crowds to and from the business district of a great city demands a far different shape of schedule sheet during these rush periods than during the middle portion of the day. Evidently, in such a system, the frequency and timing of train

movement influence the load-curve shapes to a far greater extent than the size of each individual train unit. On the other hand, the size of motors and weight of cars used on an interurban line are of great importance in estimating the load-curve shapes because the frequency of service is relatively low.

The relative importances of these several factors are borne in mind in the following, although some of them may seem there to be given undue weight. It is realized that in an interurban system the value of the mean load on each sub-station will probably not require to be estimated within a relatively large number of amperes and that the exact timing of train units will be a variable quantity. Similarly, it is realized that a sufficiently accurate load-curve could probably be estimated without considering several of the variables here considered. Therefore it

will be borne in mind that the purpose of the railway example here used is rather one of illustration of method than quantitative example, and, although the application of method herein outlined may not seem altogether congruous, it is hoped that the choice of example can be excused. The development of the method is made with the above facts in mind.

P A R T I

DESCRIPTION OF METHOD

PART I.

The size and kind of equipments used on the cars play important roles in influencing the shapes and especially the values of the load-curves. It is realized that the method of attacking the problem of choice of equipment will depend largely upon the character of the line considered. The following method was here used.

The size, weight, and character of cars were first determined from the kind of service, speed, and traffic contemplated. The weight and character of the cars and the number per train then determined the friction-curve. The approximate number of stops per mile was then found for each class of service by examination of profile and character of country. It was then assumed that the equipments used for both express and local service would, in this case, be the same. For maximum

conditions the express service was dealt with. Knowing the schedule speed to be maintained, and the number of stops per mile, the maximum speed necessary was approximated by examination of the curves of Plate II. When the maximum speed had been found, the approximate General Electric Horse-Power rating per motor was found from the tons per motor. Several motors were then selected from those suitable and from these an individual choice was made.

Alternating-current motors were considered at first but finally rejected because of difficulty in obtaining the necessary information about them. Several direct-current 500-600 volt motors were then selected. The individual choice was then made as follows: From the general characteristics of each motor were plotted general speed-tractive-effort curves as shown in the various preliminary plates and the proper friction curve was drawn

across each. The gear-ratio required to obtain the necessary maximum speed on level and the steady running current were then seen at a glance. From their values the probable suitability or unsuitability of the motor was determined at once. If the motor was considered a competitor its characteristics were plotted for the proper gear-ratio. Test run-sheets were then plotted for each preliminary choice and from these the probable performance of each was estimated. In the cases of the General Electric machines the proper data were available with which to estimate their probable temperature rises. From each test run-sheet the schedule-speeds and energy consumptions were plotted against stops per mile. From the weight of each complete equipment, the number of its motors, its energy consumption, ability to maintain schedule-speed, probable temperature rise, etc., the choice

of equipment was made. Owing to inability to obtain estimates of cost from manufacturers it was assumed that the cost of each equipment varied directly as its weight. This seemed to be as rational a method of procedure as any under the circumstances.

When the equipment had been chosen the problem of load-curve study was attacked. It was at once realized that this problem was very intricate and could not be lightly entered upon. Moreover, it was realized that a change of any one of many variables would cause some kind of change in the load-curves in question so that the original choice of conditions became at once a difficult and important matter. In any case when the equipment had once been chosen it was seen that the chief remaining variables were the location of sub-stations, the distribution of feeder material between them, the stops, including duration, location,

etc., and the timing of train units. It was considered that the general conditions concerning operation of any kind of train, its stops, their locations, etc., would be nearly constant for that train each time it was run. Of course in no two runs would the locations and durations of all stops be the same, especially in the cases of local trains, but some kind of assumptions were necessary to a study of the system and it was believed that the above would be safer than others. It was now desired to develop a method whereby the load-curves on sub-stations, power-plant, etc., corresponding to any schedule-sheet could be easily found. With such a method in hand it would be easy to compare the desirability of various schedule-sheets from the view-point of the power-system economics.

On the previous assumptions concerning location, duration, and timing of stops,

etc., actual run-sheets covering the entire line were plotted for both kinds of service--express and local, in both directions. From these run-sheets, which showed the relations of speed, load, and distance, to time, new curves connecting load with distance were plotted so that the current value for any kind of train at any location on the line could be seen immediately. With the distance-load curves completed, and knowing the locations of cities, towns, etc., the sub-stations were located to best advantage, taking account of availability of labor, its cost, character of train-load, etc.

In few systems is the conductor between sub-stations of uniform cross-section, especially where the traffic is heavy, so the division of load due to any train unit between any two sub-stations is a complex one: the amount of load on one sub-station does not, in

such a case equal $(D - L) \times A + D$ (I)

where D = distance between sub-stations, L = distance of train from sub-station considered, and A = total load of train at the instant.

It would be possible, knowing the character of feeder distribution between sub-stations, to divide the load between them, no matter what the nature of that feeder distribution, but the case of uniform feeder was here chosen as presenting the simplest problem. Hence new curves connecting load on each sub-station with location of train between sub-stations were plotted on the assumption of uniform continuous feeder with trolley frequently tapped into it. With these curves completed, it was a simple matter to go back to the run-sheets, and from them and the proportional load-curves, to plot, for each sub-station, curves between time and load due to the passage of each kind of train. Such curves are here called compon-

ent load-curves.

It is seen that the component load-curves furnish the key to a system for easily plotting the actual load-curves. For, if the instant of passage of the train in question past the sub-station be marked on the component load-curve and the instant when that train is due at the sub-station be marked on a tracing sheet, then the tracing sheet can be shifted until the mark on the curve corresponds to the proper mark on the tracing sheet and the curve can then be traced. Thus the component of load due to that train for the time of day in question is traced and similarly other component load-curves can be traced in their proper time relation. The adding of the several components at each instant then becomes a simple matter and the actual load-curve results. Thus, having given the component load-curves of the system the actual load-curves can easi-

ly be compounded by adding the proper component load-curves in their proper time relation as shown by a schedule sheet. Of course the power-plant load-curve is the sum of the several sub-station load-curves taken in their proper time relation, correction being made for losses.

P A R T I I

C H A P T E R I

CHOICE OF CAR EQUIPMENT FOR FORT WAYNE-

SOUTH BEND AIR LINE TRACTION

COMPANY

PART II.

CHAPTER I.--The example of line used to illustrate the foregoing methods was a proposed high-speed railroad connecting Fort Wayne and South Bend, Indiana. The distance between these cities is about eighty miles, and with the proposed express running time of two hours and fifteen minutes an express schedule-speed of thirty-six miles per hour was necessary. Examination of the profile of the line showed three and one-fourth miles of city line in the City of South Bend, over which a schedule-speed of fifteen miles per hour must not be exceeded. Hence a schedule-speed of thirty-eight and one-half miles per hour over some seventy-seven miles of line was necessary. A study of cities and towns from terminus to terminus showed seven where express passenger stops would pay--equal to about 0.087 per mile (See Table). From Plate II it was estimated that a maximum

speed of about forty-six miles per hour would maintain the required schedule speed. The energy consumption would seem, also, to be about fifty-one Watt-hours per ton-mile.

It had been decided to use a three-compartment car seating about sixty persons. The body of such car would probably be about fifty-eight feet long, and, with a steel underframe, weigh about 37,000 pounds. Baggage to the extent of 2,000 pounds was allowed; 9,000 pounds were assumed for passengers; and 2,000 for contingencies. A compressor weighing 2,000 pounds was assumed, each truck was assumed at 10,000 pounds, and a uniform allowance of 16,000 pounds was made for equipment. The judgment of this last allowance may be questioned because all equipments for the same service would not be equally heavy. However, the difference between the weights of any two equipments to perform the service would be

such a small proportion of the total as not to warrant the necessity of preparing new friction-curves, etc., for each motor. Hence a fifty-eight foot car weighing 88,000 pounds complete was assumed.

The choice of friction-curve was next taken up. Several curves were considered in their relation to the assumed type of car, and the final choice was based on the following formula due to Armstrong:

$$F = G + 0.133V + \frac{0.35V^2}{nT} (1 + 0.1n)(2)$$

Where F = friction in pounds per ton, V = speed in miles per hour, n = number of cars in train, and T = total tons of train weight, (2,000 pounds per ton). Upon the advice of a prominent engineer this was modified and used as follows:

$$F = G + 0.133V + \frac{0.35V^2}{(n+1)T} (1.1 + 0.1n) \quad (3)$$

the symbols carrying the same meanings as above. The further assumption of a braking

deceleration of 1.25 miles per hour per second was made, this corresponding to a braking-effort of 131. pounds per ton on a two percent down grade, rotational inertia neglected.

An estimate of the size of motor was next made from Plate II. For a four-motor equipment corresponding to eleven tons per motor an 80 horse-power motor, or for a two-motor equipment a 150 horse-power motor was considered a liberal estimate. Hence motors of about 75 horse-power rating were selected as four-motor competitors and motors of 125-160 horse-power rating as two-motor competitors. The following direct current motors were selected on this basis: the G. E. 73, the G. E. 66, the Westinghouse 112, and the Westinghouse 113.

For each competitor the proper gear-ratio was found and the characteristic curves plotted for that ratio. In all cases 36-inch wheels and 500 or 550 volts, as given on the

original characteristic, were assumed. Each motor was then assumed to be brought up to full voltage with an allowance of current equal to its full load rating, and a test run-sheet was plotted for each, taking account of rotational inertia. Runs of two minutes duration were allowed fifteen seconds coasting, those of five, six, and seven minutes thirty seconds coasting, and all others forty seconds coasting. The maximum run investigated was of eleven minutes duration. In each case the total kilowatt-hours--the kilowatt-hours per car-mile, the watt-hours per ton-mile, the average volts, distance, and square-root-mean-square current--were found. From these data the curves prefixed "4" in the preliminary plates were plotted. In the cases of the G. E. 73 and 66 motors the losses were plotted against time and from the total armature losses, total field losses, and thermal characteristics (not ap-

pendent) the temperature rises were estimated. All results thus obtained are found in the table of "Preliminary Results."

Lack of space prevents a more complete discussion of choice of equipment. Be it stated, however, that the G. E. 66 motor used with a gear-ratio of 34 to 60 was chosen on the assumption of 36-inch wheels and 500 volts at the motors.

C H A P T E R I I

DERIVATION OF COMPONENT LOAD-CURVES FOR
SUB-STATIONS OF
FORT WAYNE-SOUTH BEND AIR LINE TRACTION COMPANY

CHAPTER II.--With the motor choice completed the problem of plotting the actual run-sheets was attacked. It was seen that this work would be of considerable magnitude because in all some 300-350 miles of speed-time, current-time, and distance-time curve would be needed unless a short-cut method were devised. Evidently the minimum amount of work would be the plotting of 160 miles of runs, 80 miles for a north express and 80 miles for a south express train. If no short-cut were devised another like amount of local speed-time work would be needed. It was decided to reduce the speed-time work as follows: the express run-sheets would be used as the basis of the local run-sheets. Evidently the difference between the express runs and the local runs would consist chiefly in the local stops. If the train were running as shown by the express run-sheet its action as a local could thus be

found: having chosen the place of local stop the point of braking the train could be found. At this point(A)the local speed-curve would depart from that of the express. Beginning here the speed-time curve could be replotted,--making the stop, and then accelerating. Theoretically there would never come a time when the speed of the local train after its stop would equal, at some point on the track, that of an express train which had not stopped, until an express stop were reached. However, it was found that by thus replotting about 10,000 feet of run the speed at some point(B) on the track became so nearly equal to that of the express train at the same point that the two speed-time curves could be brought together with an error not greater than that in the actual plotting of the curves. Thus, if the express speed-time curve were cut off at (A) and the new section of speed-time curve

were inserted, then the express speed-time curve beginning at (B) could be joined to the end of the inserted section and there would result a local speed-time curve for that section of track. The subscripts 1, 2, 3, etc., beneath the letters (A) and (B) on the run-sheets refer to the number of the passenger stop.

In plotting the speed-time curves it was decided to employ an approximate method involving the use of dynamic-curves showing the acceleration or deceleration of the train on each of a number of grades. By tracing from the proper dynamic-curve (or by interpolating between two such curves) the amount of speed-time curve necessary to carry the train over that grade, considerable time was saved without loss of accuracy. Train resistance curves had been plotted for a number of grades and from them and the chosen

motor characteristics dynamic-curves were plotted for parallel running. They were not plotted for series running or for coasting because the amounts of such running were too small. It was now a simple matter to plot the several run-sheets, taking account of stops, curves, towns, railroad crossings, etc. All curves were reduced to equivalent grades on the uniform basis of 0.06 % grade per degree curvature and the compensated grades were then plotted against distance. This greatly facilitated the plotting of the speed-time curves because the point of change of grade could be seen at a glance by reference to the distance-time curve.

The curves show that when employing the above principles the north and south express runs differed in time by only 1 minute and 27 seconds, and the north and south local runs by only 3 minutes. The characteristics

of the runs themselves account for such insignificant differences.

The distance-load curves were now plotted for both express runs and the effects of local stops shown by broken lines. By comparing these distance-load curves the best sub-station locations were found and tabulated. Seven were decided upon and, although they were not evenly distributed, it was thought that the best locations had been chosen. Only two sub-stations were located in the country and they were placed within easy reach of towns. The others were located where it would pay to establish baggage and freight depots, thus enabling the operator to combine his duties.

When the sub-stations had been located the proportional-load curves were plotted on the basis of continuous uniform feeder with frequent taps to the trolley. These curves

were very quickly run off with the aid of a slide-rule and themselves present no features of especial interest. As with the distance-load curves the effects of local stops were shown by broken lines.

The component-load curves were now plotted, thus: beginning at the instant when, say, a north express train passed sub-station 4 it began to draw current from sub-station 3. Of course for some time most of its current came from sub-station 4, but the proportion from sub-station 3 increased until finally, when it was directly in front of that sub-station all of the current came from it. At that instant sub-station 4 ceased to supply any current to that train but gradually sub-station 2 took the load. Finally, when the train had reached sub-station 2 the load on sub-station 3 became zero. Thus it was possible, by using a proportional-load curve

in conjunction with the proper run-sheet to plot a component-load curve for each kind of train for each sub-station. On each such curve was shown, by an arrow-head, the instant of passage of the train before the sub-station.

Since these component-load curves were necessarily plotted to a small scale they were easily integrated by a planimeter to find the energy consumptions. By finding the energies of the trains approaching and receding separately, data were obtained for finding the energy consumptions to move the trains between any two sub-stations or from one end of the line to the last sub-station. These various amounts were tabulated. To enable comparisons to be drawn between the results obtained from test-run sheets and actual run-sheets, the several actual energy consumptions were reduced to what they would have been with a straight and level track. These corrections

were made by finding the difference in elevation between the two consecutive sub-stations and the curvature between them and applying the proper constants in accordance with the before-mentioned assumptions. Of course the correction for curvature was always negative, whereas that due to elevation was negative for a rise of train, and vice versa. The actual energy consumptions obtained were in accord with good modern practice.

C H A P T E R I I I

USE OF COMPONENT LOAD-CURVES

IN STUDY OF

ACTUAL LOAD-CURVES

CHAPTER III.--On any railway where the sub-station locations, cars, car-equipments, characters of the several runs, etc., are fixed, the factor most influential in the operation of the power system is the schedule . A frequent schedule will mean fairly uniform sub-station and power-plant loads with correspondingly high load-factors, whereas an infrequent schedule will mean the opposite. Moreover, the timing of the trains will be nearly as influential on the load conditions as their frequency. For if one train were to follow closely behind another the total loads would be large and infrequent. Hence the load-factors would be low. Again, trains running in opposite directions should, if possible, pass halfway between sub-stations, for then the load due to the receding train would be decreasing at the same time that the load due to the approaching train was increas-

ing. The combined load would evidently be most uniform with this arrangement. These desirable conditions cannot always be realized but they should be sought, due consideration being given, of course, to desirability of service from the standpoints both of the operating department and the public. The public wants a service providing trains at frequent nearly equal intervals, and the operating department, as well as the public, wants a safe service free from complicated train orders and lay-overs at meeting points; but, above all, free from accidents.

To illustrate the use of the component load-curves heretofore described, the schedule shown on schedule sheet 1 was assumed, little weight being given to operating and other conditions because of lack of sufficient data concerning the characteristics of the traveling public. This schedule provides two trains

each way each two hours: Express trains leave South Bend on the even hours, and local trains leave on the uneven hours. Express trains leave Fort Wayne on the half hours following the even hours, and local trains leave on the quarter hours preceding the even hours. This operation necessitates the following meeting points: 2 miles from South Bend terminus; 7.5 miles from South Bend terminus; Wakarusa; Nappanee; 36 miles from South Bend terminus; 45 miles from South Bend terminus; Kimmel; Merriam; and 73 miles from South Bend terminus,--9 in all. Of these the second, third, fourth, seventh, and eighth are stopping points for some trains. However, the third and eighth are the only ones about halfway between sub-stations.

The included time-table was prepared to show the time of arrival of each kind of train at each sub-station for this schedule.

Then it was but little work to mark on the tracing-sheet for each sub-station the time of arrival of each train and properly trace the component-load curve as thus placed. The components were then added for a sufficient number of instants to give a smooth curve, and the actual load-curve was the result. The actual load-curve was plotted for only about 2-1/4 hours, this covering a complete load cycle.

From the actual load-curves the mean loads were found and plotted as heavy lines. The area of the actual load-curve above the mean load line was evidently a measure of the ampere-hour capacity of that regulating battery needed to provide a uniform load on the rotaries: For the ampere-hours there represented were due to a load in excess of the steady load and so would need to be restored from the battery. To be exact, the steady

load should have represented the actual load drawn from the sub-station, plus a steady load of such value that the total energy represented between the actual load line and the exact load line during a period of two hours would represent the total battery and accessory losses during those two hours. The efficiency of a properly chosen regulating battery working on the cycle of loads actually occurring would probably be in excess of 92%, so the actual load as shown, divided by 0.92, would give the actual rotary load. With a battery acting both for storage and regulation, the efficiency would probably have been not over 80%. In fact, it is a question whether or not a battery of the size actually needed for regulation would be installed because of its small dimensions, but no provision was here made for storage.

The factors determining the sizes of

of the units in the sub-stations would be: First, the average load; Second, the maximum load; Third, the forms of the load-curves; Fourth, costs; Fifth, the standard size available; Sixth, the transportation facilities; Seventh, the factor of reliability of service; Eighth, provision for growth; Ninth, the presence or absence of batteries. In choosing the units for a system, all of these things should be considered, due weight being given to each. In the present case, costs other than rough estimates were not available, so the factors considered were chiefly those relating to the load-curves and the results obtained from them.

The average loads are seen to range from about 90 to 175 amperes (without battery corrections), or from about 98 to 190 for floating batteries, and from about 115 to 220 for storage batteries. The case of a float-

ing battery will first be considered. If we assume a single standard size of rotary it should be considered amply able to carry 250 amperes continuously: This corresponds to 125 K. W. capacity at 500 volts. In the event of a breakdown at any sub-station, each adjacent sub-station would carry about 50% overload. Units of the above size seem ridiculously small, but the presence of batteries would make the use of larger machines unnecessary.

On the contrary, if no batteries were used the machines would need to be much larger. In this case, one unit of 300 K. W. or two of 150 K. W. capacity each would be needed per sub-station for the schedule outlined. The effect of regulating batteries is at once apparent. With a 250 ampere machine and battery at sub-station 4, the load-factor on the rotary would be about 76% for a 24-hour day, or about 48% for a 15-hour day. For sub-

sub-station 7 (having the smallest load), the corresponding factors would be about 38% and 24%. On the contrary, without the batteries the figures for sub-station 4 would be 29% and 18% (assuming a 600 ampere machine), and for sub-station 7 they would be 14-1/2% and 9%. However, in the latter case, one 300 ampere machine could be used when the results would be 29% and 18%, as with sub-station 4.

The power-plant load-curve was not plotted because its load factor would be considerably larger than that of any one sub-station, and because the application of the method of using the component-load curves was amply shown by the sub-station load curves. By correcting the sub-station load curves and adding them all in their proper time relation, the power-plant load-curve would result.

P A R T I I I

CONCLUSIONS

PART III.

CONCLUSIONS.--The use of speed-time and the related curves in solving various electric railway problems has become a matter of considerable importance. Such problems generally arise in connection with the choice of car motor-equipment to operate a given schedule, the betterment of schedule possible by using electric traction in place of some other motor-power, the best gear-ratio to use on an old equipment to maintain a new schedule, the effects of schedules of various kinds on the energy-consumption, the heating of the motors, etc., the proper acceleration to use in any case, etc., etc. In fact, most of the present applications of speed-time principles are concerned chiefly with the car equipment.

It is a question whether or not the application of speed-time work is often or ever carried so far as accurately to prede-

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termine the sub-station, power-plant, and feeder-loads, etc. There are several reasons for this: First, the amount of engineering work required in the plotting of the curves is generally great, particularly in the case of a long interurban line. Here, especially, the amount of such work is large and the capital invested is so small a quantity as not always to warrant the work. Second, the obtaining of the exact sub-station and feeder-loads would be an extremely tedious piece of work if no short cuts were devised, and, so far as the author is aware, no such method as that herein outlined is in general use. Moreover, without such a short cut as this one, the entire plotting of the sub-station and feeder-loads would have to be gone through for each schedule, thus enormously lengthening the work. Third, the predetermination of location of stops, their durations, etc., and

their constancy for all runs of a given class, would sometimes be very difficult and uncertain. Fourth, the accuracy of the entire work depends on the choice of the proper friction curve, but so many experiments have been conducted to find the resistances of various kinds of trains that a very close estimate of the proper curve is possible. Fifth, and lastly, such factors as voltage, the personal equation, etc., are variables, so some error will be introduced by them at times, although this should be small.

The chief of the above enumerated objections is seen to be that of amount of work. Naturally, a small investment will not warrant as great an engineering outlay as a large and important one. Stated another way, the choice of equipment for an interurban line of no great importance will be dictated largely by the capital at hand, such units and feeder

material being purchased as the sellers of the bonds can pay for. On the other hand, such a job as that of building an elevated line or subway or electrifying a steam suburban line involves so much capital, and the sizes of units will be such as to make worth while a quite accurate choice of units, including the adoption or rejection of batteries, etc. Similarly, the amount of outlay for feeders and other conductors will be so great as to warrant a careful investigation of the loads coming upon them. Again, the accuracy of predetermination of runs, their stops, etc., can be made great because the trains will always stop at the same places and the lengths of their stops will be quite uniformly constant. Also, the variables, such as voltage, etc., are largely eliminated by the use of automatic acceleration. Lastly, the amount of work involved in finding the

various loads is smallest in the case of such lines, because they are short, and the number of trains making each kind of run is great. Hence, it would seem that the very plants most able financially to bear the expense of careful investigation, as above, are those best adapted physically to such investigation.

A number of interesting fields are opened up to the investigator by the use of the component-load curves. Thus, it is but little trouble, when these curves have once been obtained, to find the effect of frequency of service on load factor, battery capacity, maximum loads, etc. Or, with any given frequency of service, it is not difficult to find that set of leaving times of trains which gives the lowest peak load on any given sub-station, or the lowest average on them all. Or, the effect on sub-station loads due to running special trains can be quickly

found and the most desirable times of leaving best determined. Probably the most important use of the curves, however, is in connection with the desirability or undesirability of batteries, whether used simply to regulate load or also to store energy. Such uses as these last are especially interesting because the choice or rejection of a battery depends largely on an accurate knowledge of the load-curve. Finally, one use in particular should be mentioned. It is a comparatively simple matter to find the exact distance load-curve of any existing train operation by the use of a properly equipped test-table, several of which are in use. Having given the distance load-curves actually occurring, all errors due to inaccuracy of friction-curves, etc., are eliminated and accurate component load-curves can be obtained. Then, if desired, the desirability or undesirability of

any proposed schedule from the point of view of power system economics can quickly be determined with assurance that the results are accurate.

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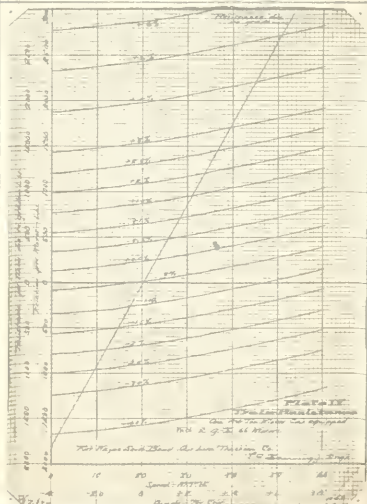
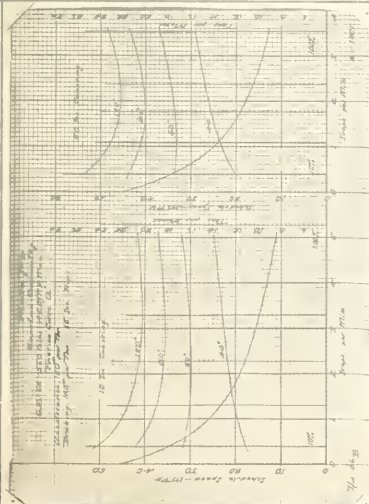
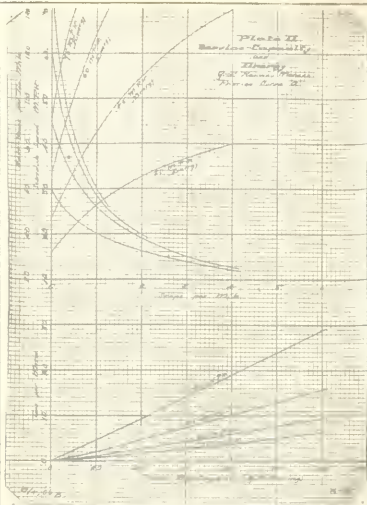
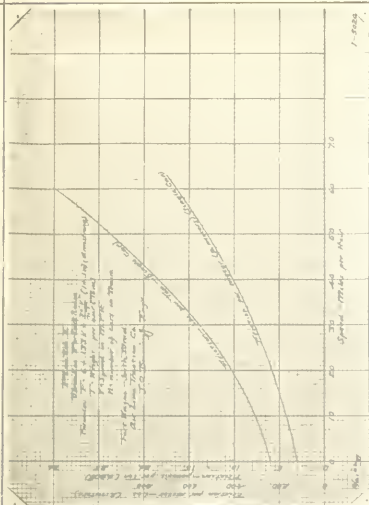
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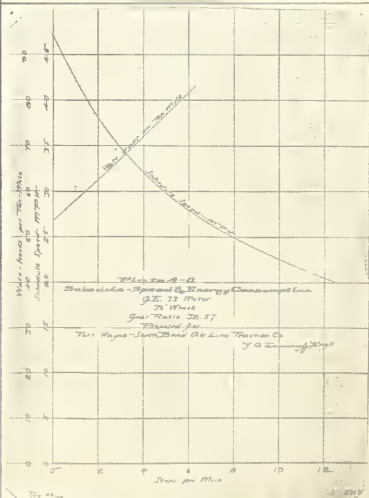
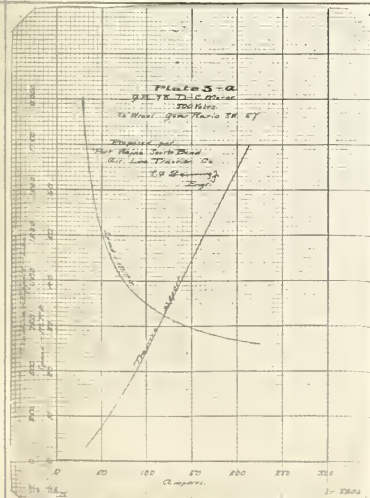
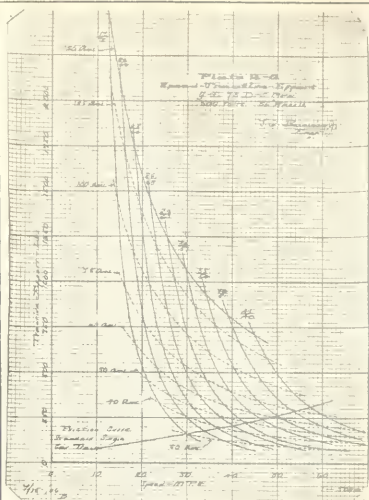
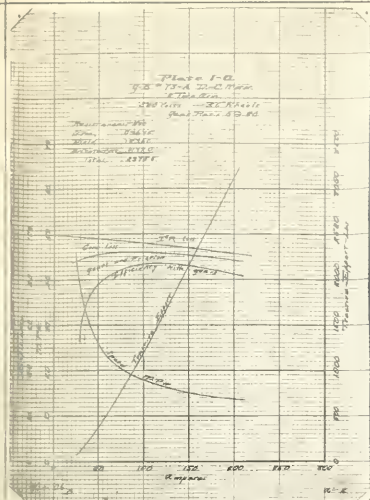
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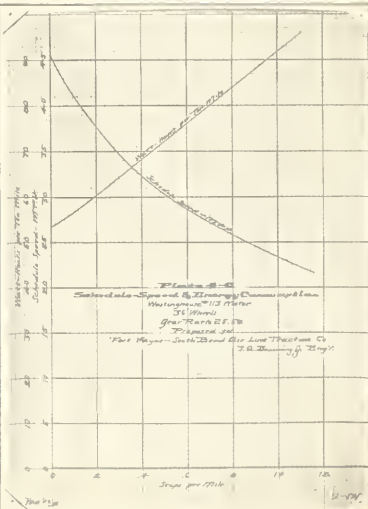
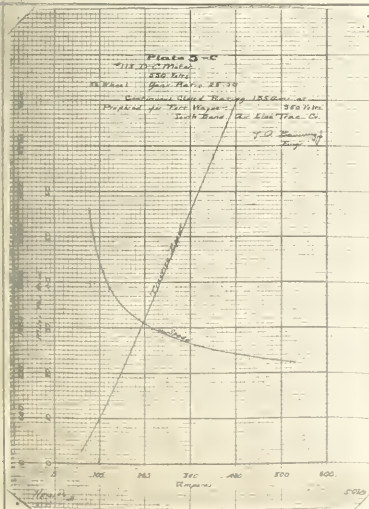
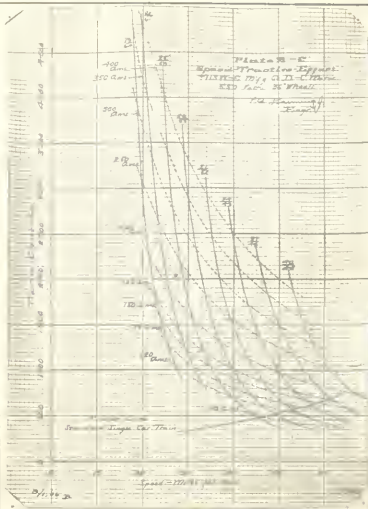
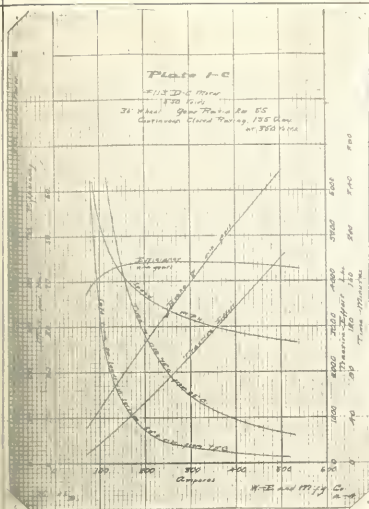
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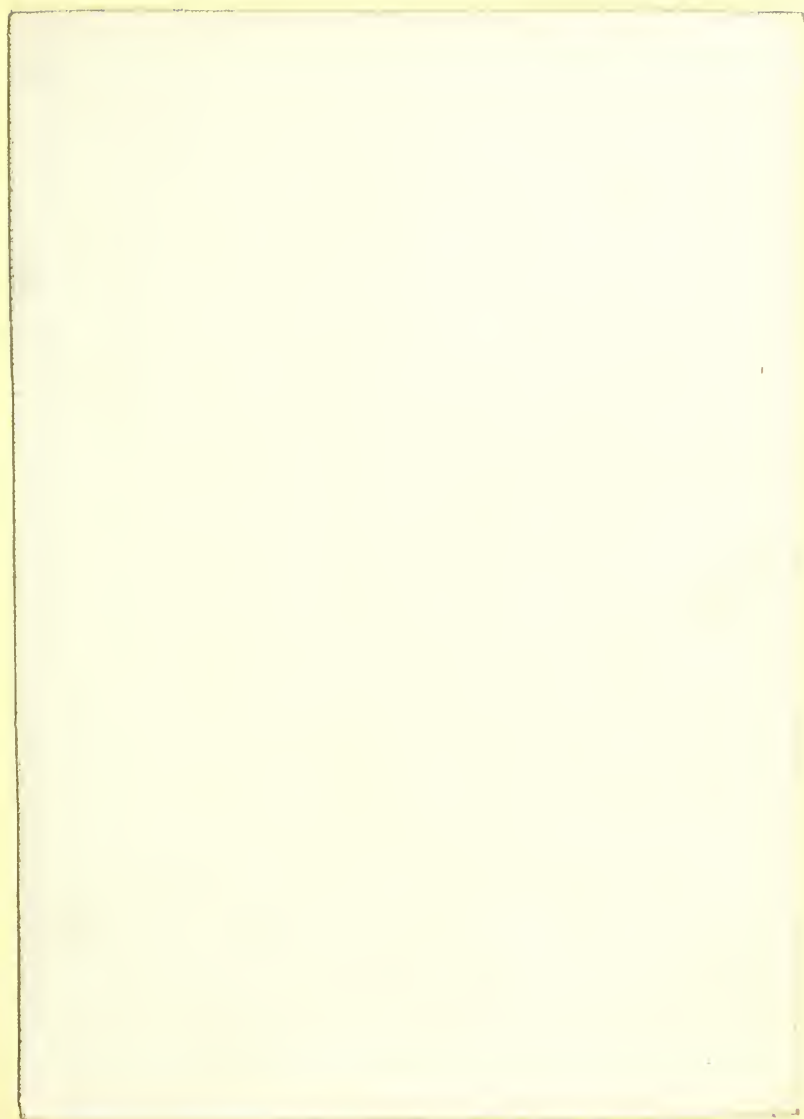
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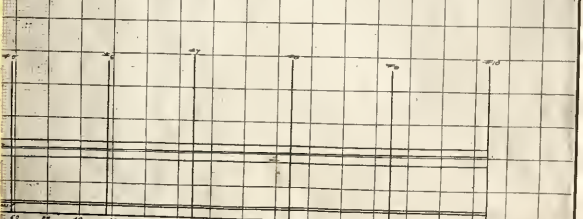
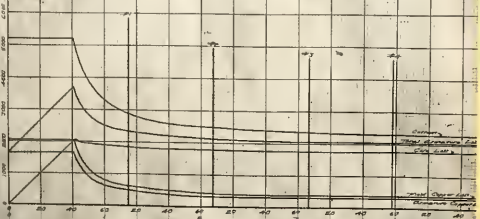
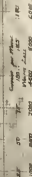
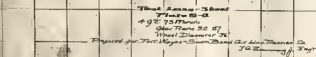
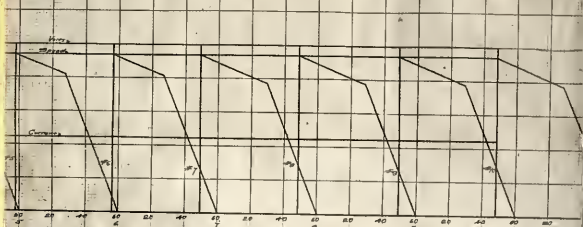
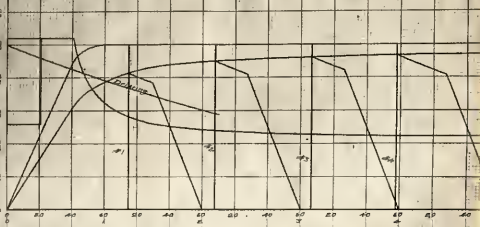
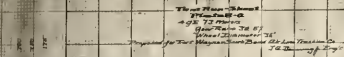












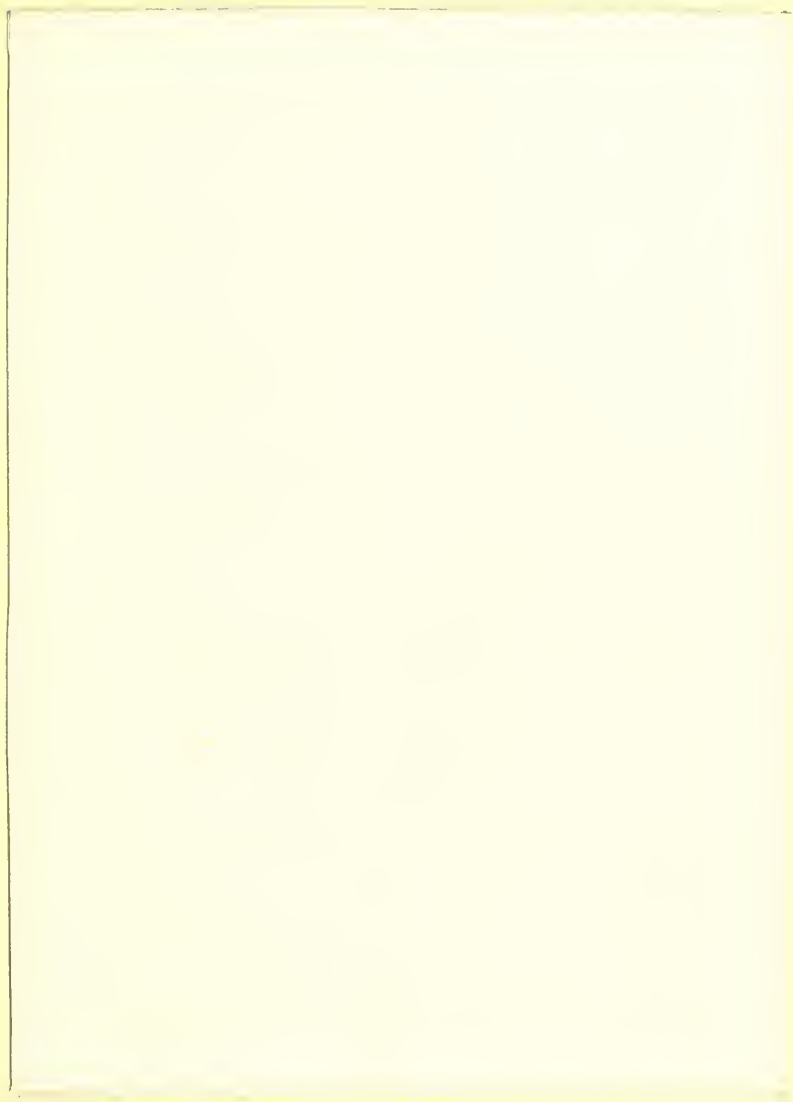




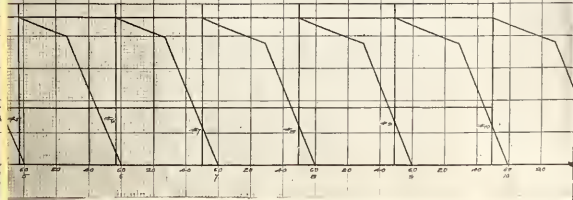
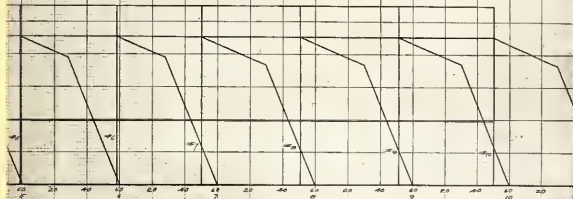




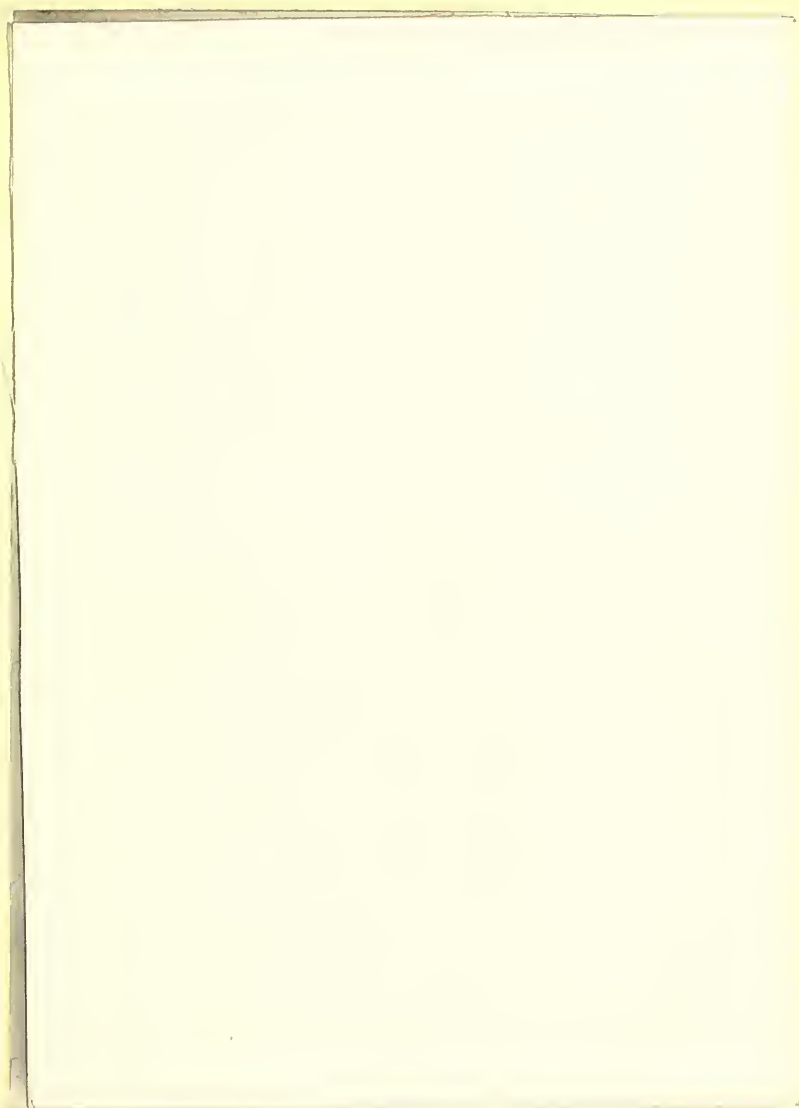














Flat Plate Chart

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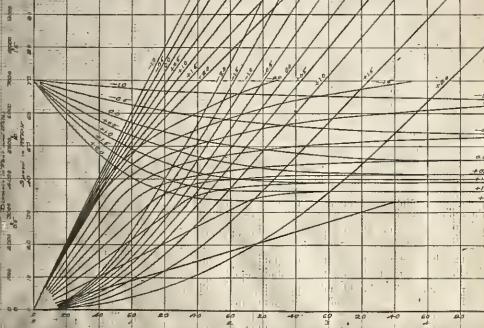
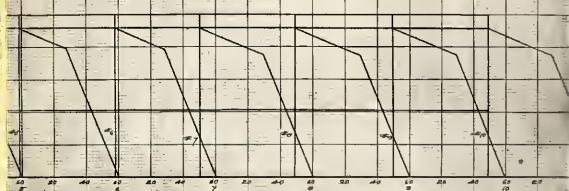
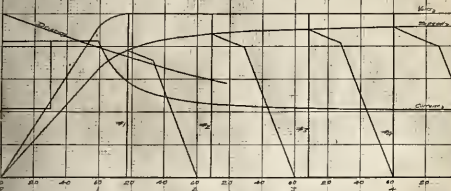
250 sq. ft. area

Flat Plate Chart

Plate No. 23

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J. B. Brown, Jr., Eng.

Area in Square Feet
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1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
2100 2200 2300 2400 2500 2600 2700 2800 2900 3000
3100 3200 3300 3400 3500 3600 3700 3800 3900 4000
4100 4200 4300 4400 4500 4600 4700 4800 4900 5000
5100 5200 5300 5400 5500 5600 5700 5800 5900 6000
6100 6200 6300 6400 6500 6600 6700 6800 6900 7000
7100 7200 7300 7400 7500 7600 7700 7800 7900 8000
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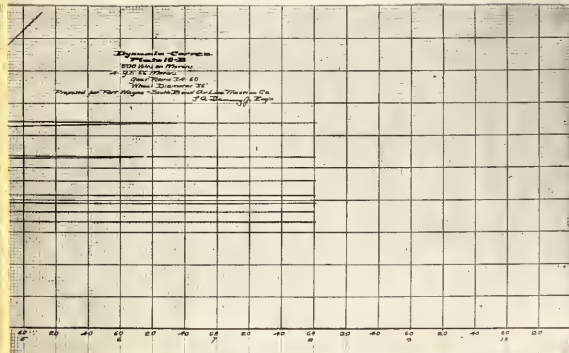
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250 sq. ft. area

Dynamite Chart

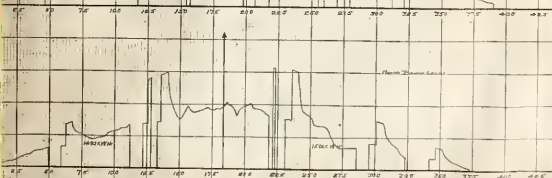
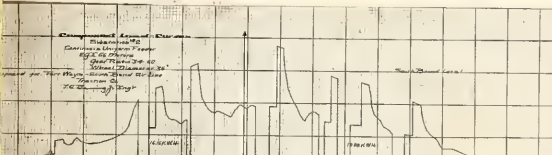
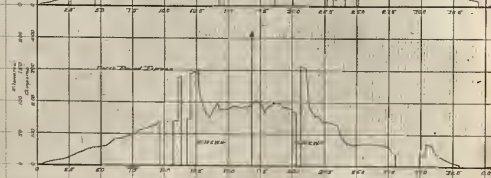
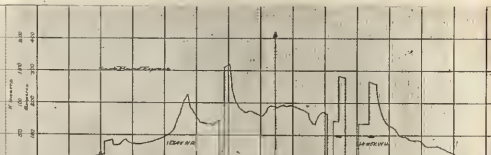
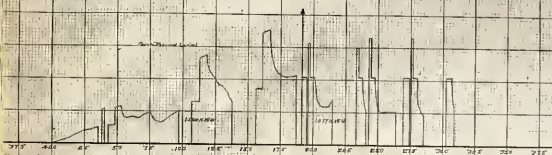
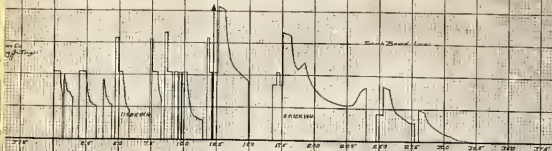
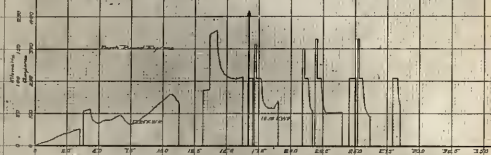
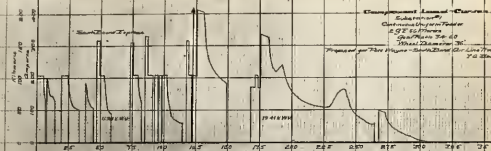
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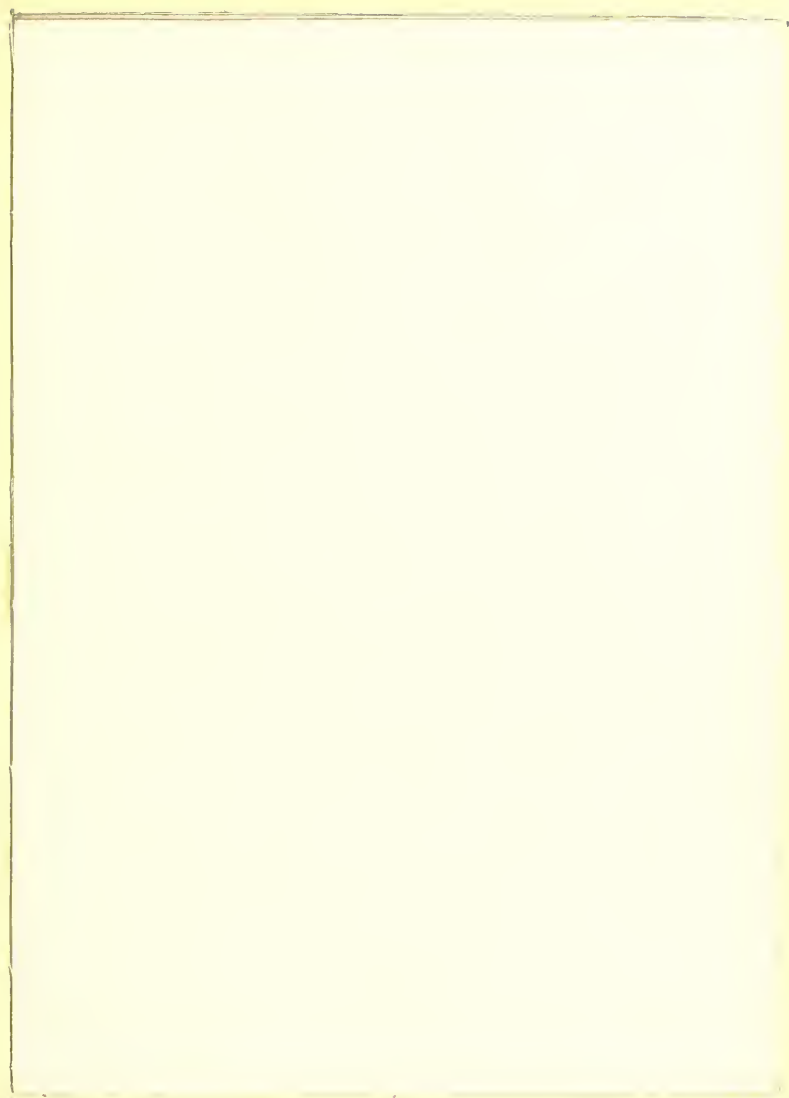
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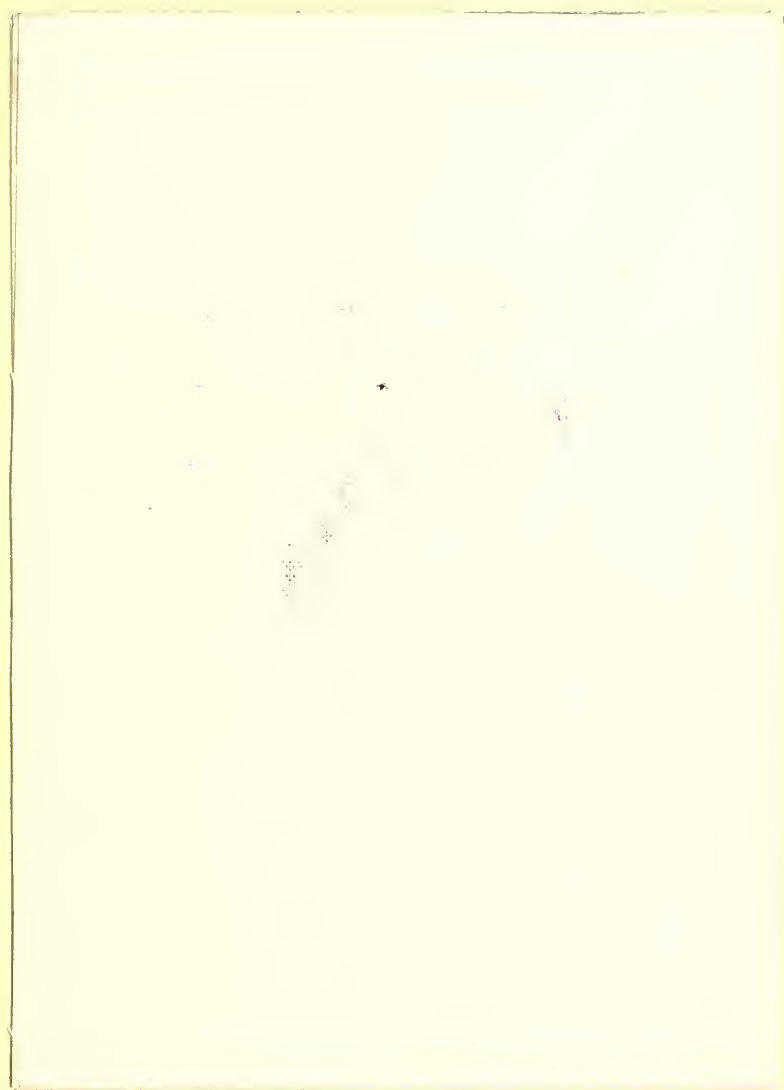


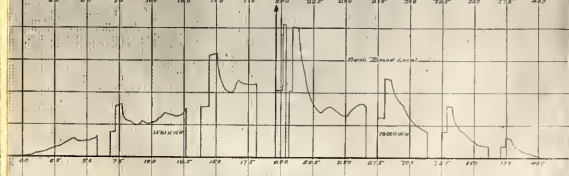
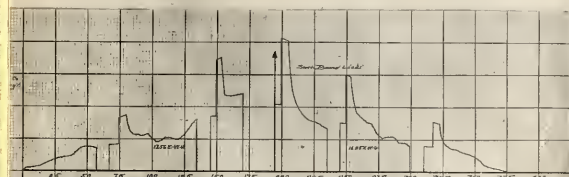
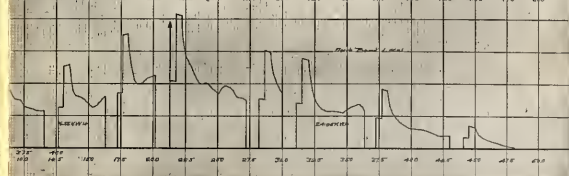
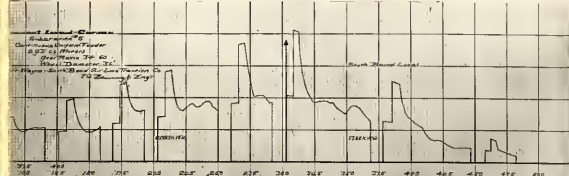
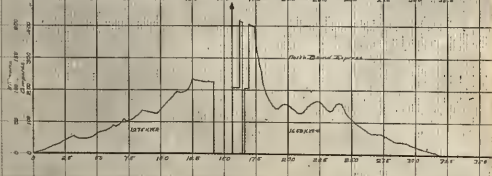
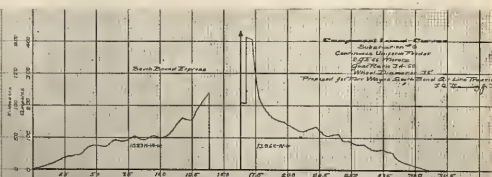
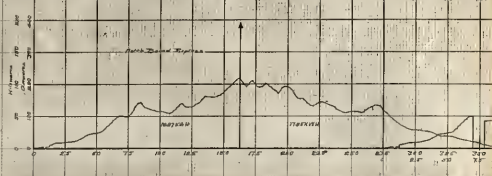
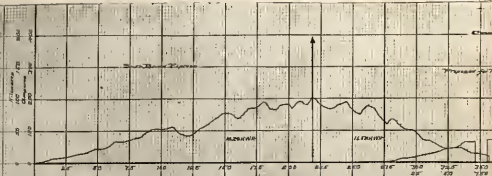




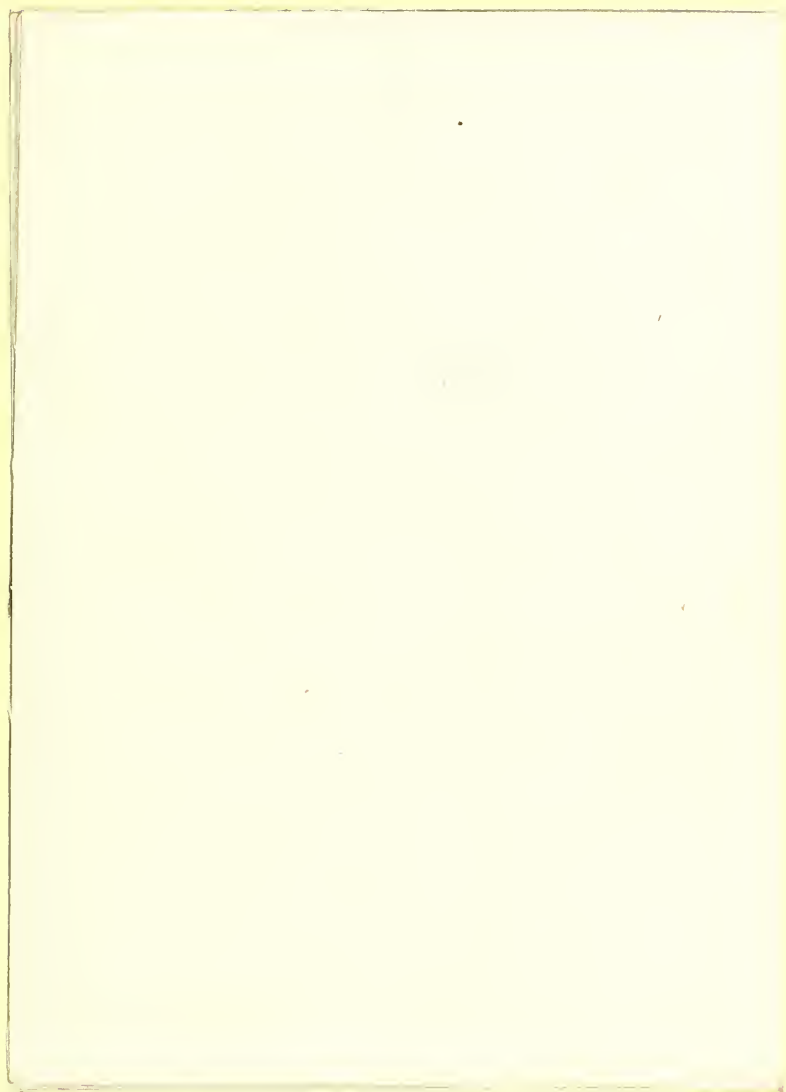


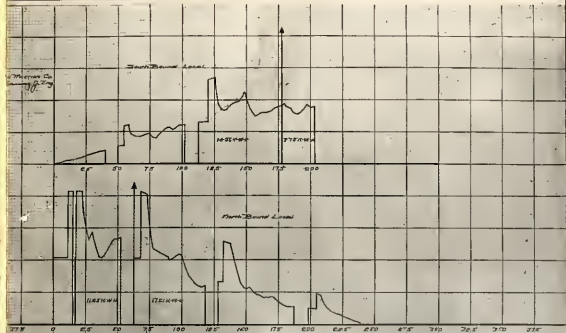
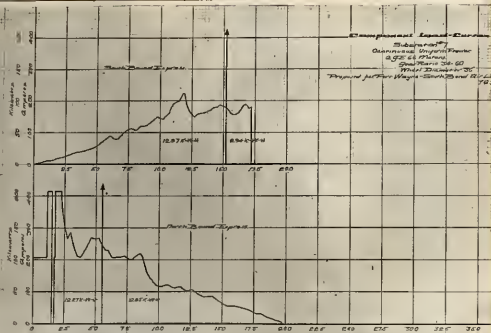


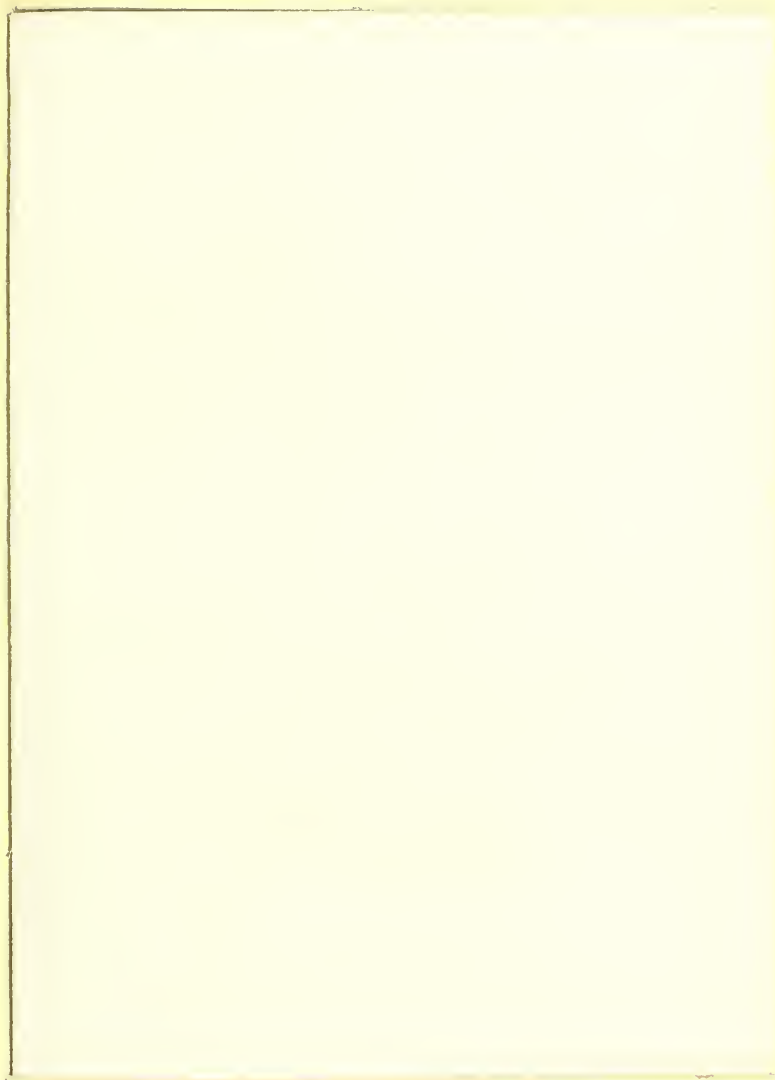


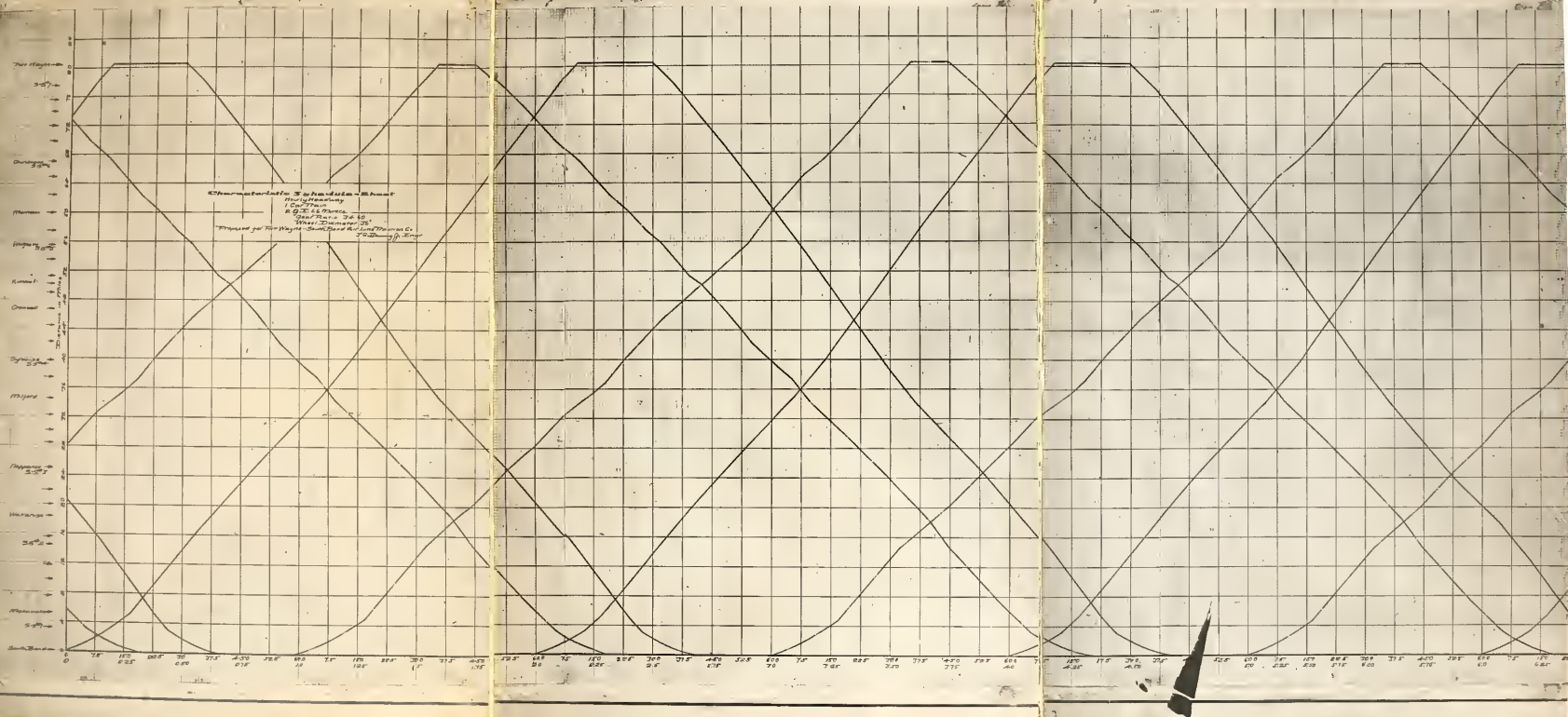




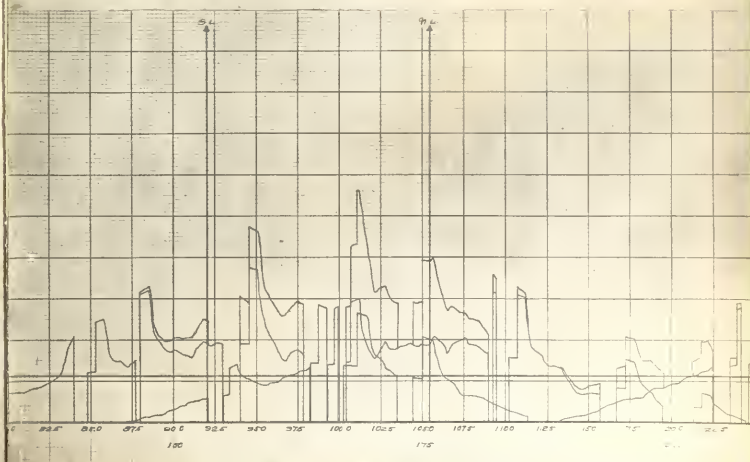
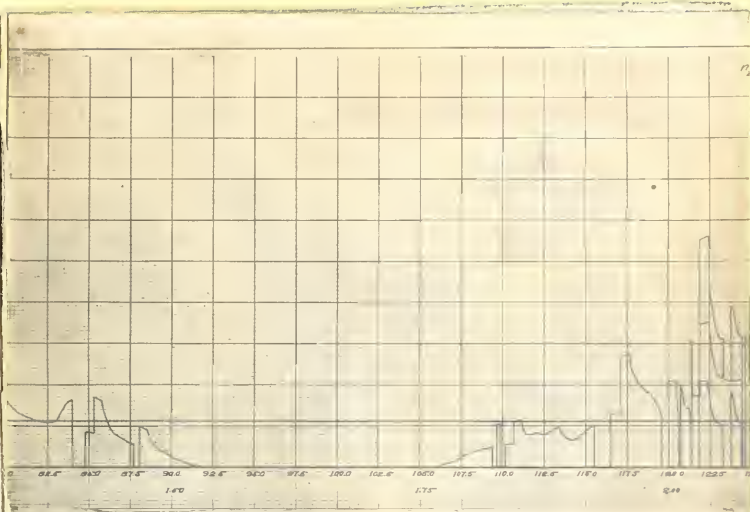


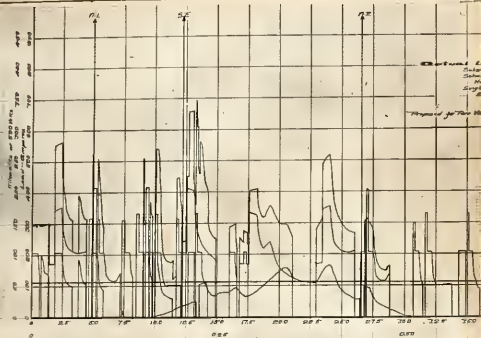




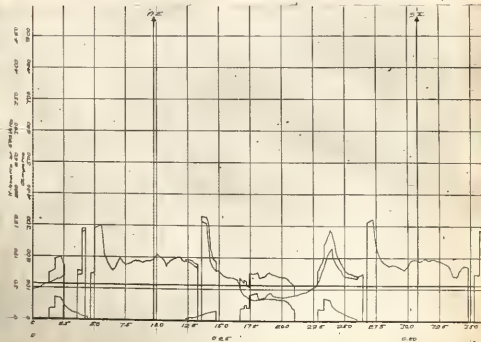
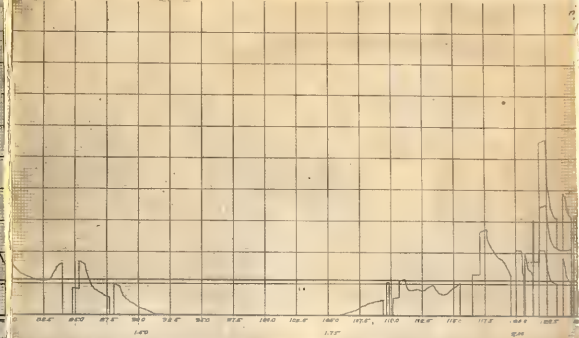
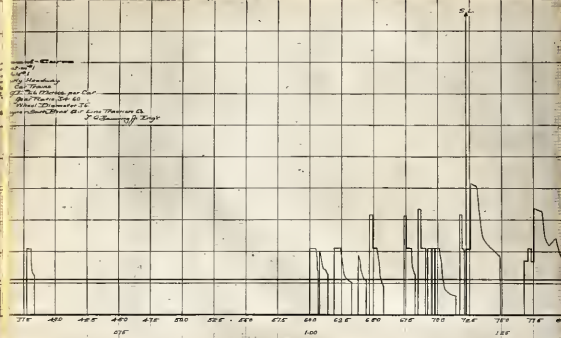




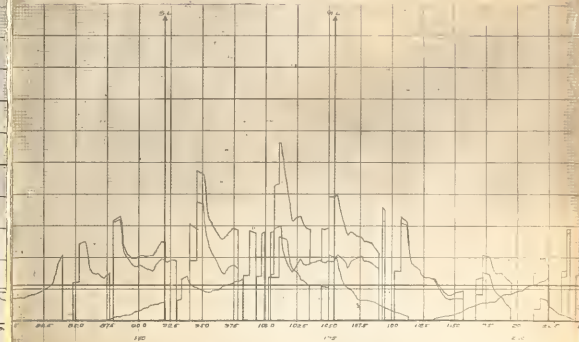
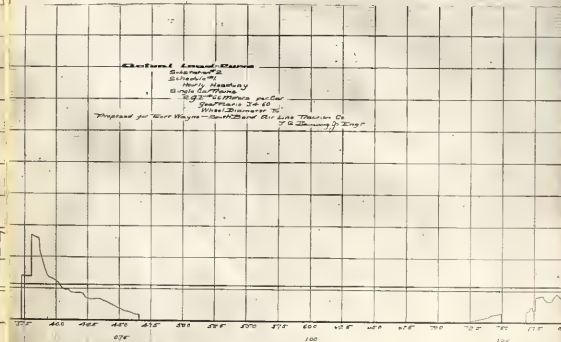


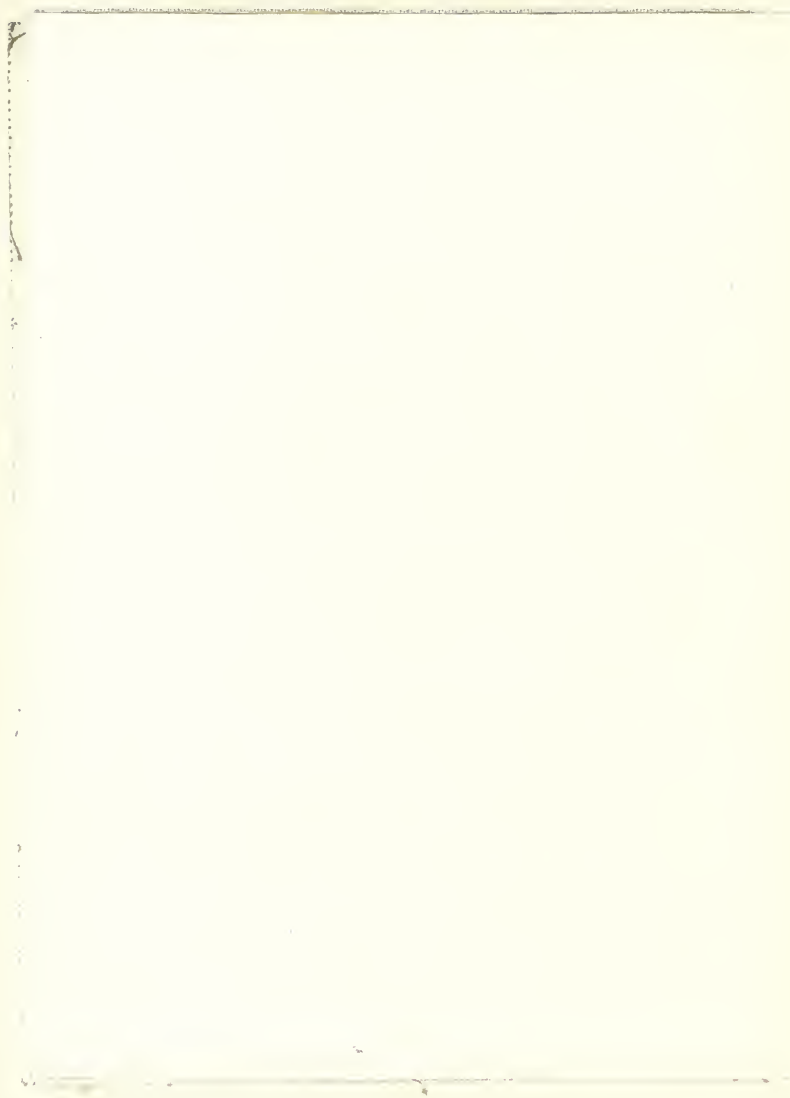


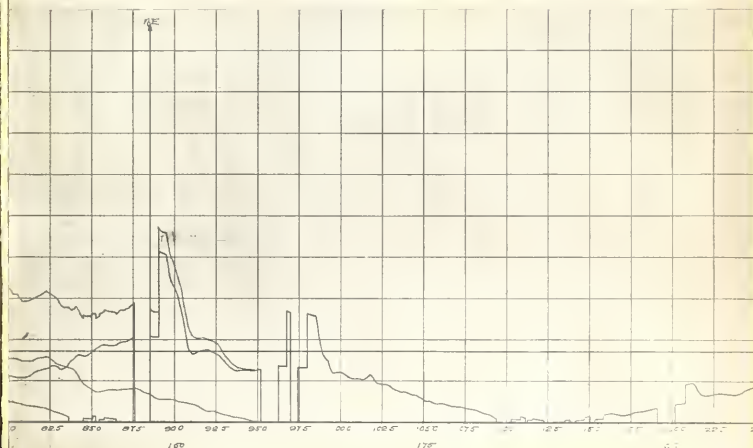
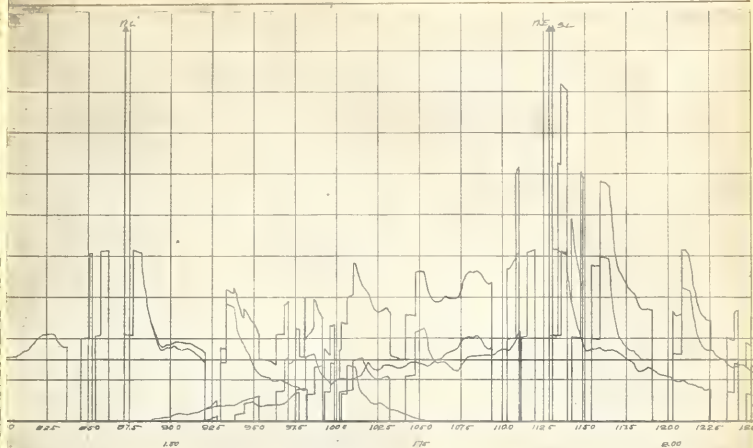
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 By
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 Weight
 Diameter
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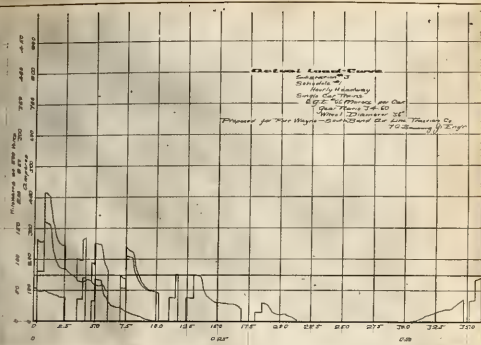


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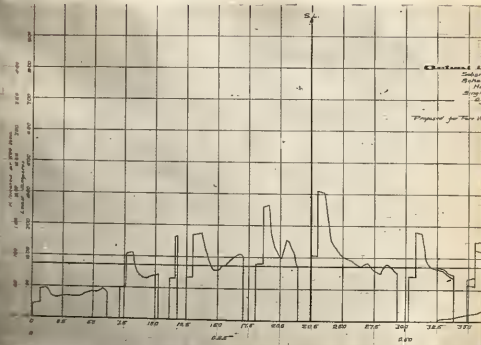
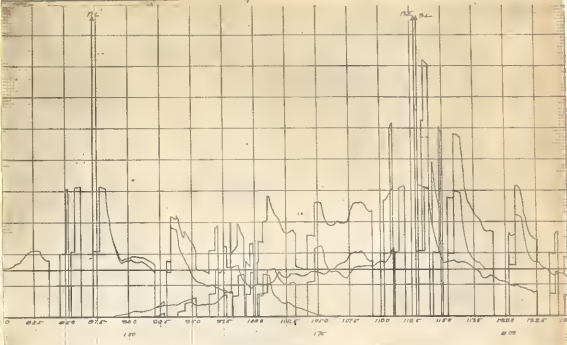
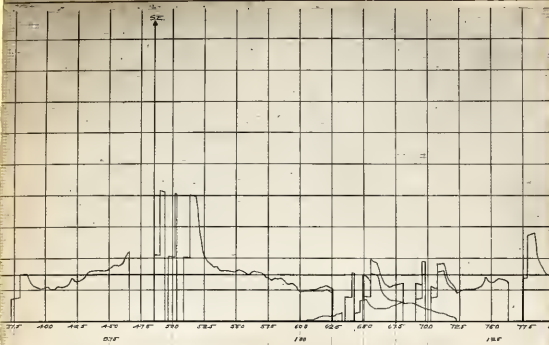




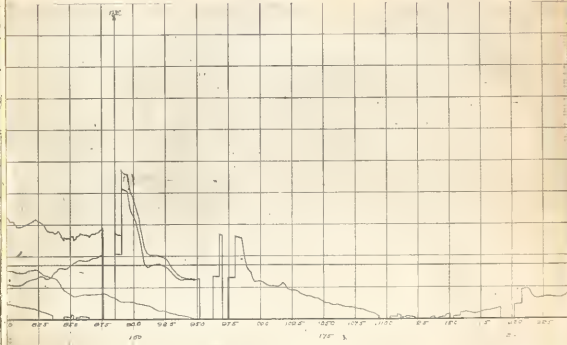
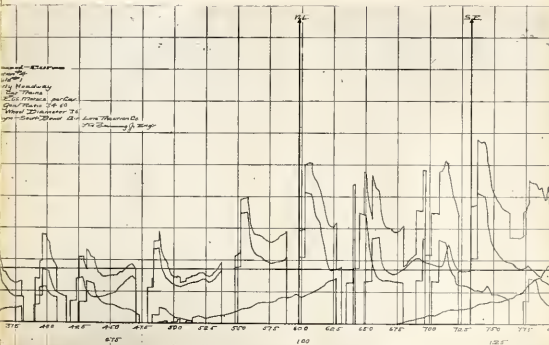


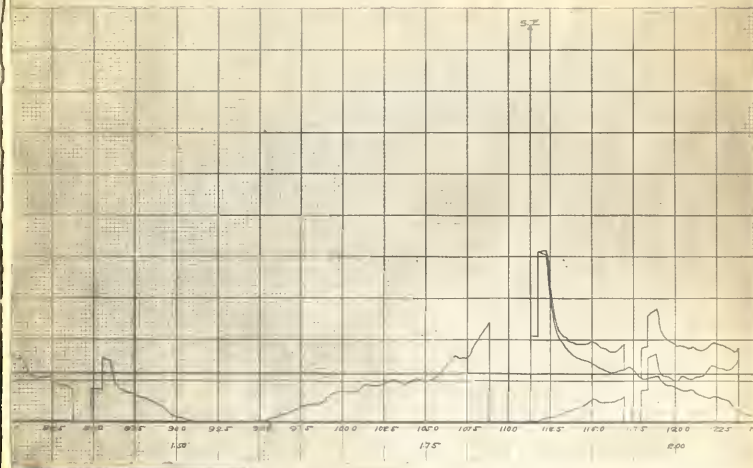
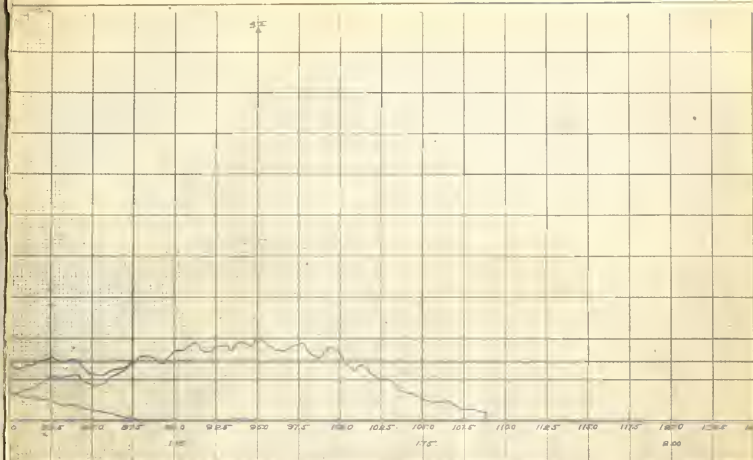


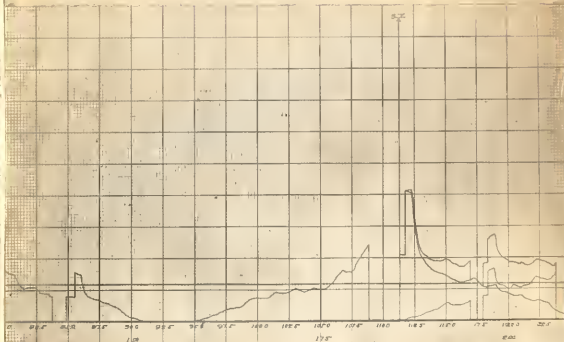
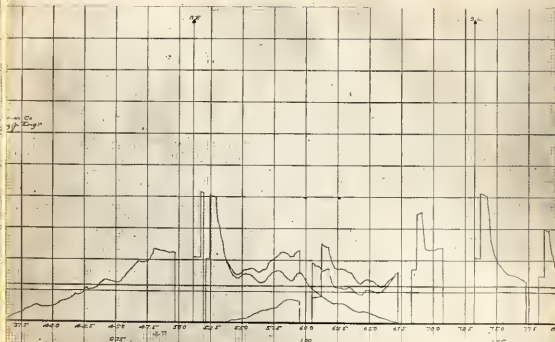
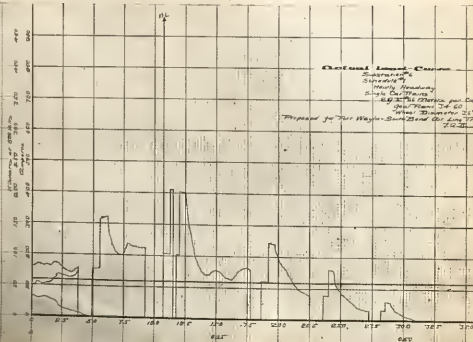
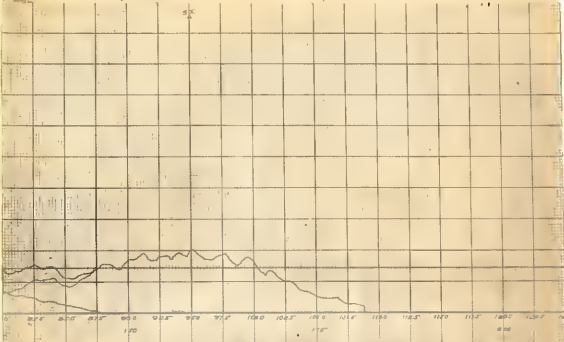
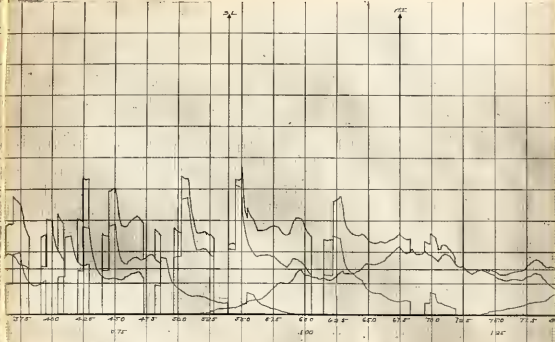
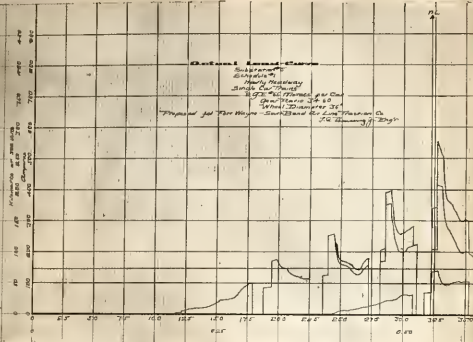
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 Hourly History
 Sample No. 1000
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 Steel Thickness 1/4"
 Prepared for the High-Speed Steel Co. Tucson, Ariz.
 by E. J. King



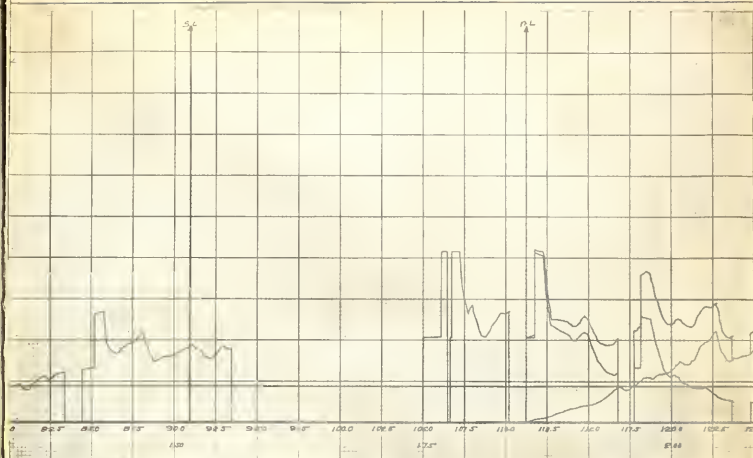
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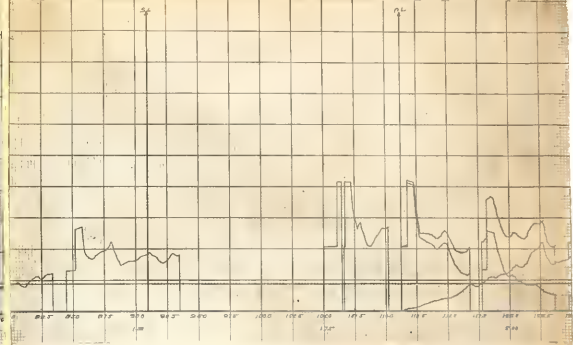
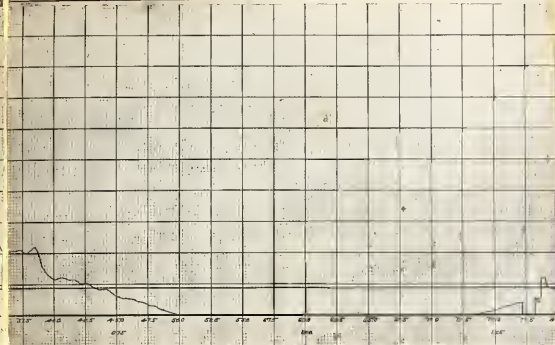
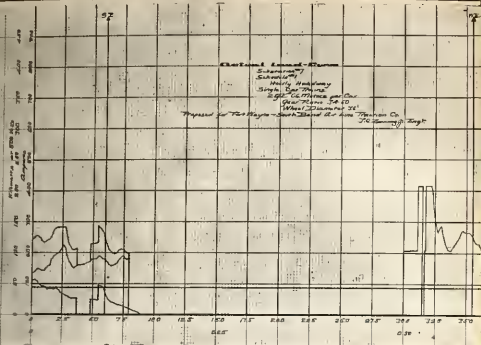


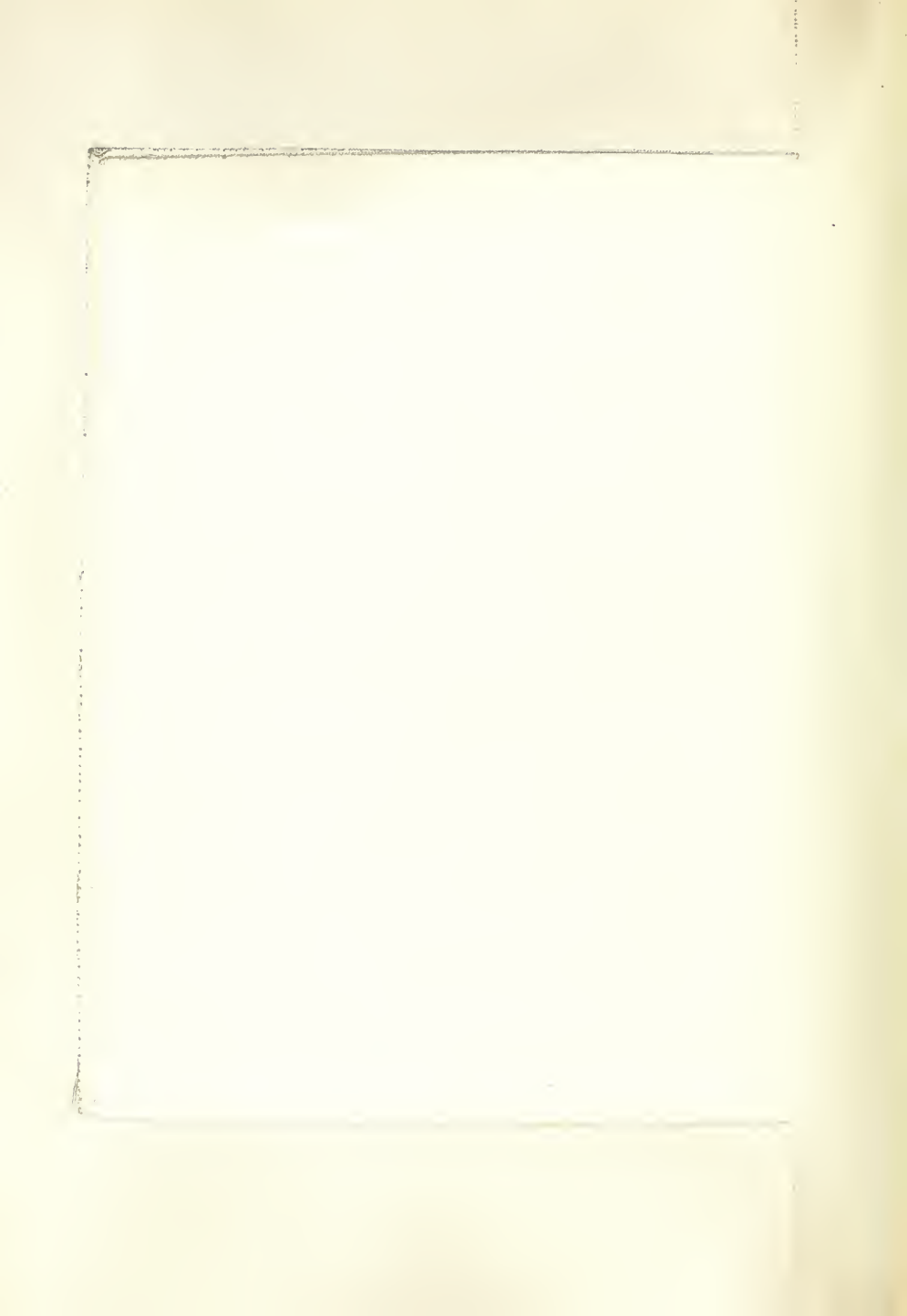












-XXXI-

Preliminary Results from Test Runs. Fort Wayne - South Bend Air Line Traction Company General Electric #13 Motor, Gear Ratio 32:57

Title	Run	1	2	3	4	5	6	7	8	9	10
Time, minutes		2	3	4	5	6	7	8	9	10	11
Distance, miles		0866	159	236	312	390	468	544	622	703	779
Equivalent stops per mile		1155	0689	0424	0321	0236	0214	0184	0161	0143	0128
Schedule Speed - 30 sec Stop		208	273	316	341	360	374	384	393	401	406
Total K-W-H for Run		391	502	774	935	1118	1310	1478	1645	1826	2016
K-W-H per Car mile		451	365	328	299	287	280	278	264	260	260
Watt-hours per Ton-Mile		1025	830	746	680	652	636	618	600	589	586
Mean I ² for Run		802	758	718	686	660	653	638	631	624	618
Average Volts at motor		173	239	303	386	404	416	418	427	433	439
Armature Temperature Rise		766	760	752	740	732	731	724	725	729	738
Field Temperature Rise		829	797	764	735	724	723	705	708	701	707

General Electric #6 Motor, Gear Ratio 34:60

Title	Run	1	2	3	4	5	6	7	8	9	10
Time, minutes		2	3	4	5	6	7	8	9	10	11
Distance, miles		0752	146	221	295	370	449	523	600	675	756
Equivalent stops per mile		173	0685	0453	0339	0270	0233	0191	0166	0140	0133
Schedule Speed - 30 sec Stop		181	250	296	322	342	359	369	379	385	395
Total K-W-H for Run		339	516	694	835	1005	1175	1326	1490	1661	1835
K-W-H per Car mile		451	354	314	283	272	268	257	249	246	244
Watt-hours per Ton-Mile		1025	804	714	643	619	595	575	564	559	554
Mean I ² for Run		1425	1350	1295	1239	1209	1185	1160	1145	1137	1126
Average Volts at motor		125	213	277	302	333	355	363	364	365	406
Armature Temperature Rise		814	815	820	754	791	809	740	739	750	745
Field Temperature Rise		918	892	904	795	830	800	780	769	779	776

Westinghouse Electric #113 Motor, Gear Ratio 25:58

Title	Run	1	2	3	4	5	6	7	8	9	10
Time, minutes		2	3	4	5	6	7	8	9	10	11
Distance, miles		0945	166	240	315	390	466	539	615	691	768
Equivalent Stops per mile		106	0692	0416	0317	0257	0214	0185	0163	0145	0139
Schedule Speed - 30 sec Stop		227	285	320	344	360	373	380	389	394	401
Total K-W-H for Run		332	566	789	995	1275	1251	1410	159	177	195
K-W-H per Car mile		415	337	307	284	276	259	246	239	236	234
Watt-hours per Ton-Mile		967	765	692	645	622	610	595	582	582	577
Mean I ² for Run		1422	1274	1226	1239	1204	1174	1146	1130	1119	1107
Average Volts at motor		2215	300	353	375	401	421	427	447	452	460

Westinghouse Electric #112 Motor, Gear Ratio 24:65

Title	Run	1	2	3	4	5	6	7	8	9	10
Time, minutes		2	3	4	5	6	7	8	9	10	11
Distance, miles		0824	1575	226	301	377	453	529	605	680	758
Equivalent Stops per mile		1215	0660	0446	0332	0265	0221	0189	0165	0147	0132
Schedule Speed - 30 sec Stop		1975	260	301	329	349	362	373	382	389	395
Total K-W-H for Run		740	424	633	759	909	1059	1187	1330	1430	1635
K-W-H per Car mile		417	319	280	252	241	232	224	222	219	216
Watt-hours per Ton-Mile		977	725	616	573	542	530	520	511	490	491
Mean I ² for Run		699	640	604	574	552	540	526	522	517	508
Average Volts at motor		225	21	32	339	367	381	397	399	408	416

TG Banning Jr. Eng'r

Energy Pump - Y. R. 100

Train Eng. Res.

South Sound Local 20 Loo. Train Company

North Bound Express

Run	50	40	30	20	10	5	2	1	0	50	40	30	20	10	5	2	1	0
Distance, Miles	2.20	0.97	4.5	5.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Number of Stops below 10 MPH	5	1	3	5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Mileage per Train-Mile Actual	90	70.5	47.25	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7
Mileage per Train-Mile (Actual)	90	70.5	47.25	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7
Energy Consumption per Change of Direction	-1.24	1.24	-1.03	+0.70	-1.13	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70
Energy Consumption per Curvature	-1.70	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Total Energy Consumption	-1.24	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Corrected Energy Consumption	0.00	10.75	2.52	4.39	7.76	2.7	3	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29
Corrected Mileage per Train-Mile	90	46.7	50.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0

North Bound Express

Run	50	40	30	20	10	5	2	1	0	50	40	30	20	10	5	2	1	0
Distance, Miles	3.23	1.21	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70
Number of Stops below 10 MPH	0	1	0	1	5	2	2	5	16	0	1	0	1	5	2	2	5	16
Mileage per Train-Mile Actual	12.27	25.00	20.45	22.95	40	4	5.94	26.27	10.0	20.45	25.00	20.45	22.95	40	4	5.94	26.27	10.0
Mileage per Train-Mile (Actual)	12.27	25.00	20.45	22.95	40	4	5.94	26.27	10.0	20.45	25.00	20.45	22.95	40	4	5.94	26.27	10.0
Energy Consumption per Change of Direction	-0.72	-1.00	-0.50	+0.3	-0.70	+0.3	-0.70	+0.3	-0.70	+0.3	-0.70	+0.3	-0.70	+0.3	-0.70	+0.3	-0.70	+0.3
Energy Consumption per Curvature	0.57	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
Total Energy Consumption	-0.15	-1.25	-0.75	-0.25	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95
Corrected Energy Consumption	0.70	27.25	20.27	24.70	39.25	3.23	20.29	26.27	10.0	20.29	27.25	20.27	24.70	39.25	3.23	20.29	26.27	10.0
Corrected Mileage per Train-Mile	60.0	40.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0

South Bound Local

Run	50	40	30	20	10	5	2	1	0	50	40	30	20	10	5	2	1	0
Distance, Miles	2.81	0.97	11.45	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70
Number of Stops below 10 MPH	5	2	5	0	6	3	1	1	3	5	2	5	0	6	3	1	1	3
Mileage per Train-Mile Actual	11.90	26.80	22.90	40.30	40.30	21.10	3.4	21.10	22.90	26.80	22.90	40.30	40.30	21.10	3.4	21.10	22.90	22.90
Mileage per Train-Mile (Actual)	11.90	26.80	22.90	40.30	40.30	21.10	3.4	21.10	22.90	26.80	22.90	40.30	40.30	21.10	3.4	21.10	22.90	22.90
Energy Consumption per Change of Direction	-0.24	1.24	-0.7	+0.70	-1.03	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70
Energy Consumption per Curvature	-0.70	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Total Energy Consumption	-0.70	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Corrected Energy Consumption	0.00	10.75	2.52	4.39	7.76	2.7	3	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29
Corrected Mileage per Train-Mile	60.0	46.7	50.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0

South Bound Local

Run	50	40	30	20	10	5	2	1	0	50	40	30	20	10	5	2	1	0
Distance, Miles	2.23	1.21	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70
Number of Stops below 10 MPH	1	3	4	5	7	4	3	5	3	1	3	4	5	7	4	3	5	3
Mileage per Train-Mile Actual	21	10.70	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45
Mileage per Train-Mile (Actual)	21	10.70	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45	20.45
Energy Consumption per Change of Direction	-0.24	1.24	-0.7	+0.70	-1.03	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70	+0.70
Energy Consumption per Curvature	-0.70	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Total Energy Consumption	-0.70	-0.70	-0.24	-0.40	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Corrected Energy Consumption	0.00	10.75	2.52	4.39	7.76	2.7	3	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29	5.05	20.29
Corrected Mileage per Train-Mile	60.0	46.7	50.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0



-XXXIII-

Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time
1325	0 05	2.05	40.40	11.00	19.4	30.75	61.30	15.40	10.17	30.87	50.30	11.90	20.10	32.25	57.50		
2	13.00	33.0	49.40	15.4	14.85	33.80	54.20	14.93	15.06	37.85	40.4	14.6	19.08	39.00	54.30		
3	14.75	5.44	41.25	50.90	12.35	22.83	4.30	50.90	2.40	7.14	45.50	5.0	14.25	26.12	49.40	49.10	
4	15.10	10.75	44.80	49.30	18.84	21.81	46.25	52.70	21.04	23.60	54.30	49.4	27.23	24.58	59.40	51.10	
5	2.91	7.86	36.40	50.60	18.24	16.59	35.70	59.60	16.56	24.85	48.1	5.40	30.83	17.62	40.22	47.80	
6	2.75	16.80	32.00	55.00	10.23	13.96	31.00	26.90	15.81	19.00	40.10	52.00	3.56	16.85	37.40	40.80	
7	12.27	12.86	19.70	76.60	12.87	2.94	11.20	53.6	25	7.21	23.80	71.80	14.56	37.5	20.3	54.10	

Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time	Comp	Comp	Time
1325	0 05	2.05	40.40	11.00	19.4	30.75	61.30	15.40	10.17	30.87	50.30	11.90	20.10	32.25	57.50		
2	13.00	33.0	49.40	15.4	14.85	33.80	54.20	14.93	15.06	37.85	40.4	14.6	19.08	39.00	54.30		
3	14.75	5.44	41.25	50.90	12.35	22.83	4.30	50.90	2.40	7.14	45.50	5.0	14.25	26.12	49.40	49.10	
4	15.10	10.75	44.80	49.30	18.84	21.81	46.25	52.70	21.04	23.60	54.30	49.4	27.23	24.58	59.40	51.10	
5	2.91	7.86	36.40	50.60	18.24	16.59	35.70	59.60	16.56	24.85	48.1	5.40	30.83	17.62	40.22	47.80	
6	2.75	16.80	32.00	55.00	10.23	13.96	31.00	26.90	15.81	19.00	40.10	52.00	3.56	16.85	37.40	40.80	
7	12.27	12.86	19.70	76.60	12.87	2.94	11.20	53.6	25	7.21	23.80	71.80	14.56	37.5	20.3	54.10	

General Time-Tables

Fort Wayne - South Bend Air Line Traction Co

Trains South

Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00	59.50	60.00	60.50	61.00	61.50	62.00	62.50	63.00	63.50	64.00	64.50	65.00	65.50	66.00	66.50	67.00	67.50	68.00	68.50	69.00	69.50	70.00	70.50	71.00	71.50	72.00	72.50	73.00	73.50	74.00	74.50	75.00	75.50	76.00	76.50	77.00	77.50	78.00	78.50	79.00	79.50	80.00	80.50	81.00	81.50	82.00	82.50	83.00	83.50	84.00	84.50	85.00	85.50	86.00	86.50	87.00	87.50	88.00	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50	99.00	99.50	100.00
Station	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00</																																																																																																																																																																		

J. Q. Jamney & Son

Trains North

Station	From Mayne	From
1	1,400	1,400
2	2,100	2,100
3	3,600	3,600
4	4,700	4,700
5	5,800	5,800
6	6,900	6,900
7	8,000	8,000
8	9,100	9,100
9	10,200	10,200
10	11,300	11,300
11	12,400	12,400
12	13,500	13,500
13	14,600	14,600
14	15,700	15,700
15	16,800	16,800
16	17,900	17,900
17	19,000	19,000
18	20,100	20,100
19	21,200	21,200
20	22,300	22,300
21	23,400	23,400
22	24,500	24,500
23	25,600	25,600
24	26,700	26,700
25	27,800	27,800
26	28,900	28,900
27	30,000	30,000
28	31,100	31,100
29	32,200	32,200
30	33,300	33,300
31	34,400	34,400
32	35,500	35,500
33	36,600	36,600
34	37,700	37,700
35	38,800	38,800
36	39,900	39,900
37	41,000	41,000
38	42,100	42,100
39	43,200	43,200
40	44,300	44,300
41	45,400	45,400
42	46,500	46,500
43	47,600	47,600
44	48,700	48,700
45	49,800	49,800
46	50,900	50,900
47	52,000	52,000
48	53,100	53,100
49	54,200	54,200
50	55,300	55,300
51	56,400	56,400
52	57,500	57,500
53	58,600	58,600
54	59,700	59,700
55	60,800	60,800
56	61,900	61,900
57	63,000	63,000
58	64,100	64,100
59	65,200	65,200
60	66,300	66,300
61	67,400	67,400
62	68,500	68,500
63	69,600	69,600
64	70,700	70,700
65	71,800	71,800
66	72,900	72,900
67	74,000	74,000
68	75,100	75,100
69	76,200	76,200
70	77,300	77,300
71	78,400	78,400
72	79,500	79,500
73	80,600	80,600
74	81,700	81,700
75	82,800	82,800
76	83,900	83,900
77	85,000	85,000
78	86,100	86,100
79	87,200	87,200
80	88,300	88,300
81	89,400	89,400
82	90,500	90,500
83	91,600	91,600
84	92,700	92,700
85	93,800	93,800
86	94,900	94,900
87	96,000	96,000
88	97,100	97,100
89	98,200	98,200
90	99,300	99,300
91	100,400	100,400
92	101,500	101,500
93	102,600	102,600
94	103,700	103,700
95	104,800	104,800
96	105,900	105,900
97	107,000	107,000
98	108,100	108,100
99	109,200	109,200
100	110,300	110,300

T. C. Manning, Jr. Esq.

Time of Arrival of Trains at Sub-Station

Hourly Headway

Schedule 1

[illegible]

T. A. Cunningham, Esq.



Actual Sub-Station Load Results.

Schedule #1

Hourly Headway

Fort Wayne-South Bend Air Line Traction Company

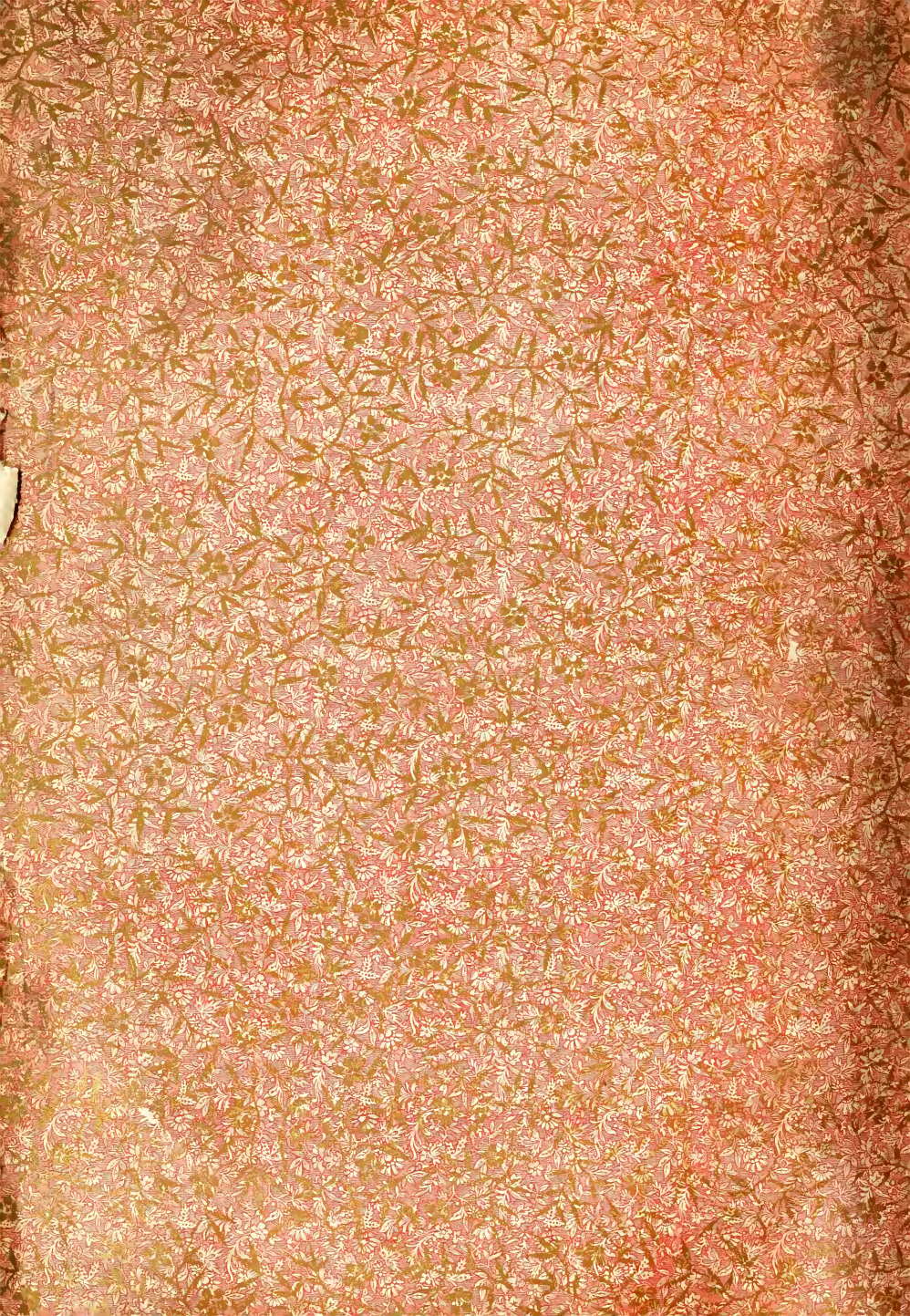
Sub-Station Loads

Name	Average Load Amperes	Average Load Kilowatts at 500 Vols	Maximum Load Amperes	Average Load + Maximum	Amperes- Hours of Battery (2 Hours)	Total Amperes- Hours Output (2 Hours)	Battery Amperes- Hours - Total	Kilowatt Hours Output per 15 Hour Day	Kilowatt- Hours Output per 365 Day Year
#1	1127	564	6920	0.163	1115	2234	0495	8460	308300
#2	1128	564	5620	0.201	1015	2256	0450	8460	308300
#3	1493	796	8190	0.183	953	2906	0319	11950	436000
#4	1719	859	5800	0.296	1079	3438	0313	12880	470000
#5	1454	727	5540	0.263	936	2908	0321	10900	397500
#6	1107	594	4160	0.205	791	2374	0333	8920	325500
#7	877	439	4160	0.210	971	1754	0553	6590	240400

J. J. Eng







XXX

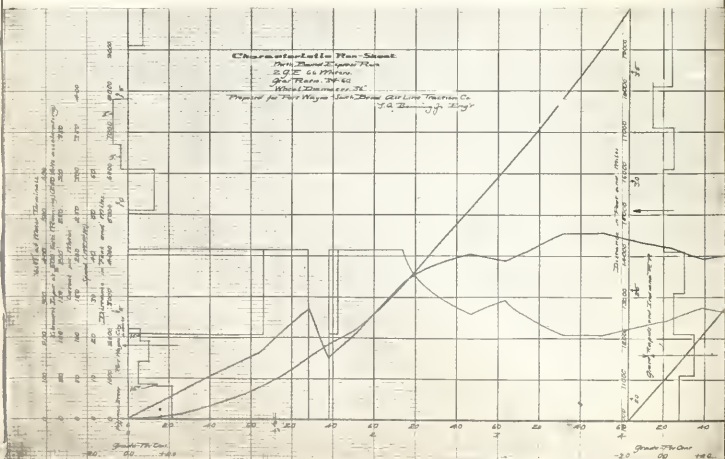
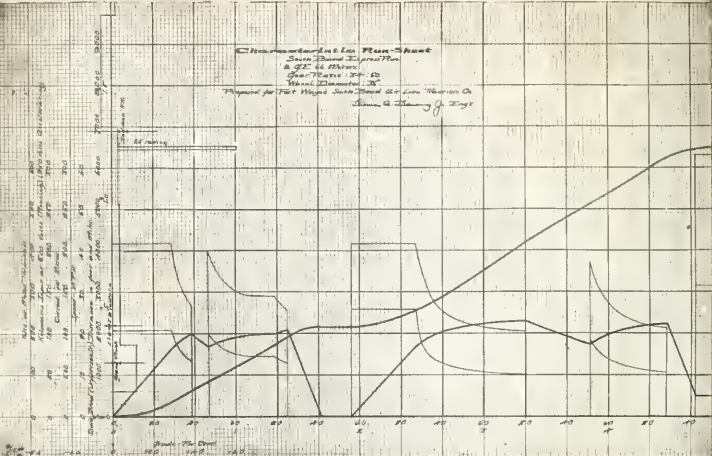


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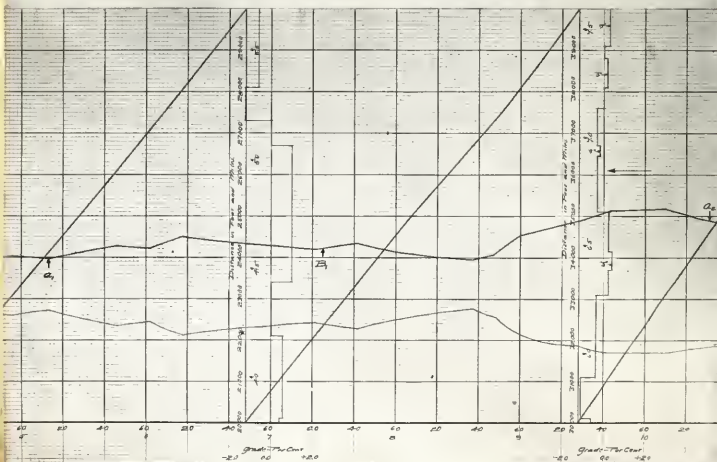
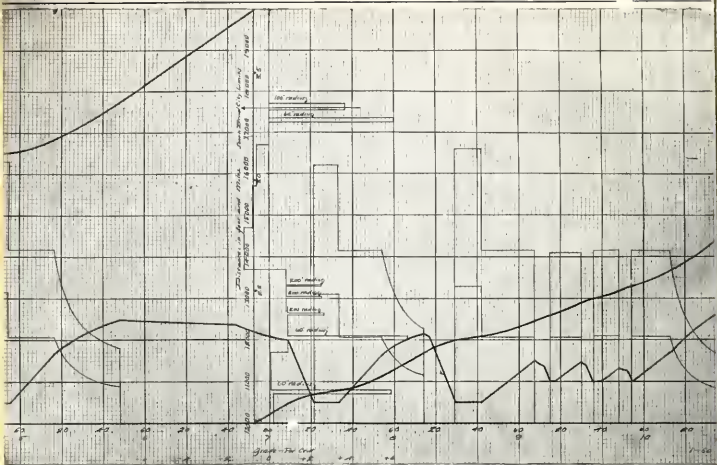
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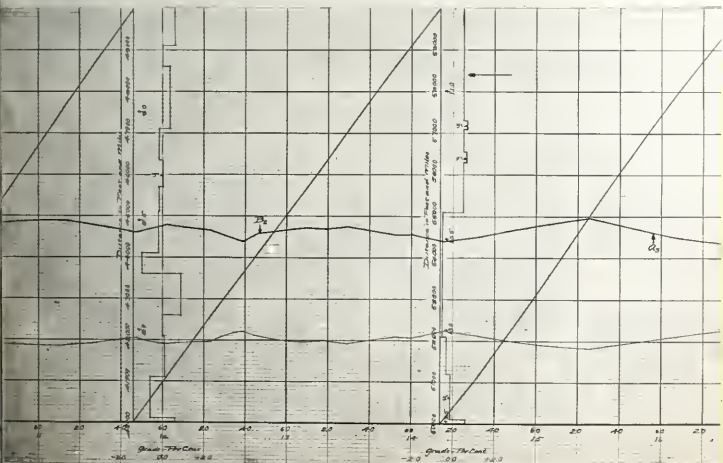
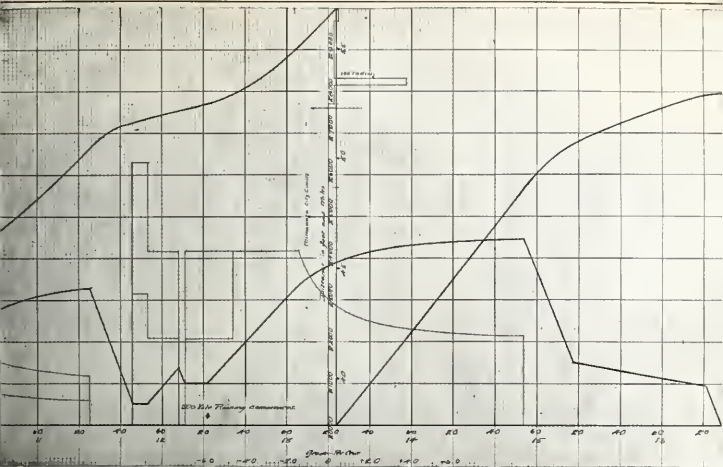


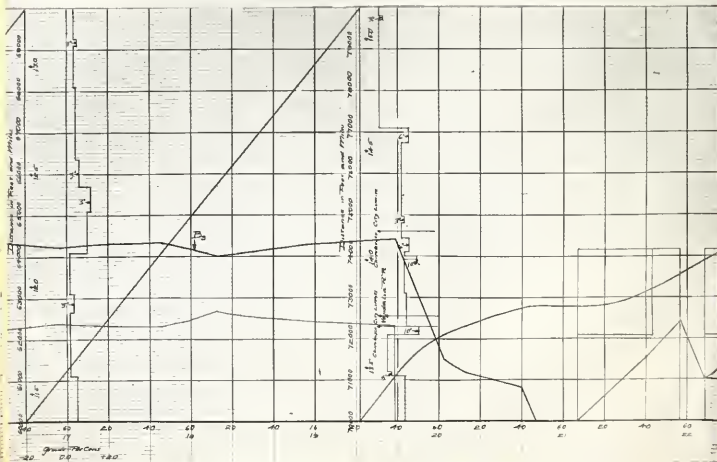
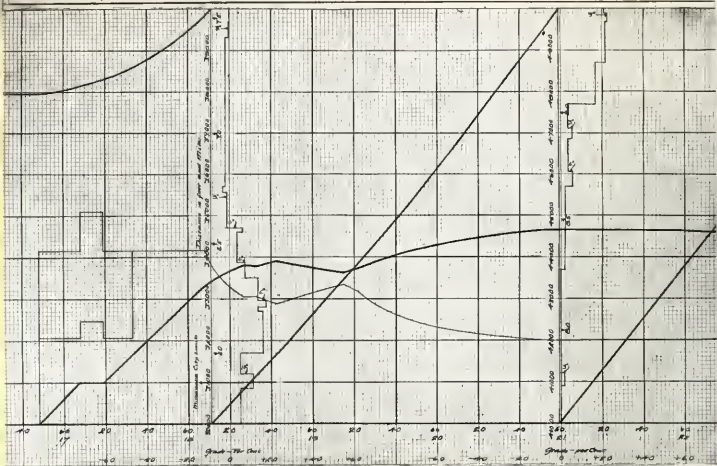
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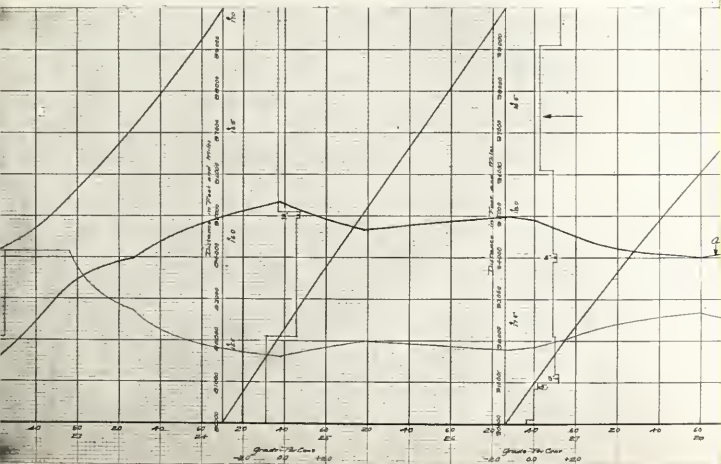
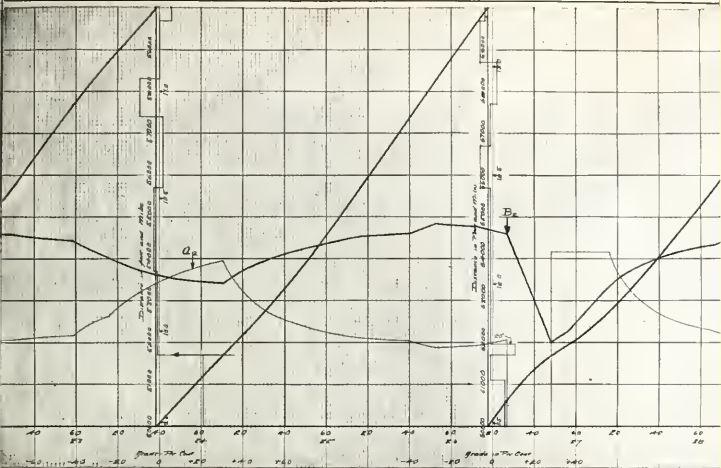


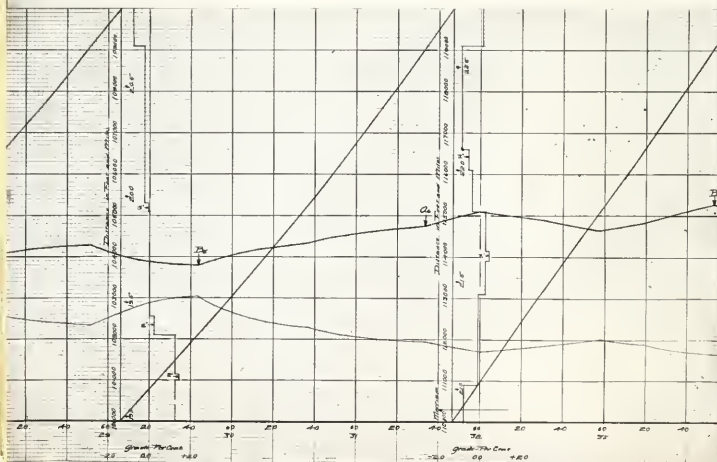
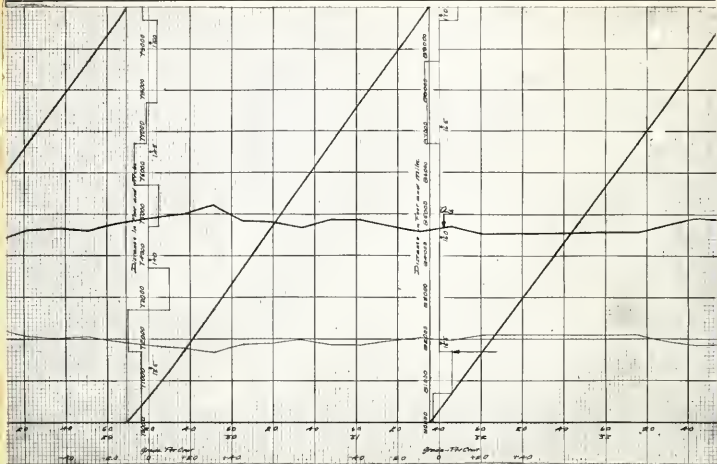


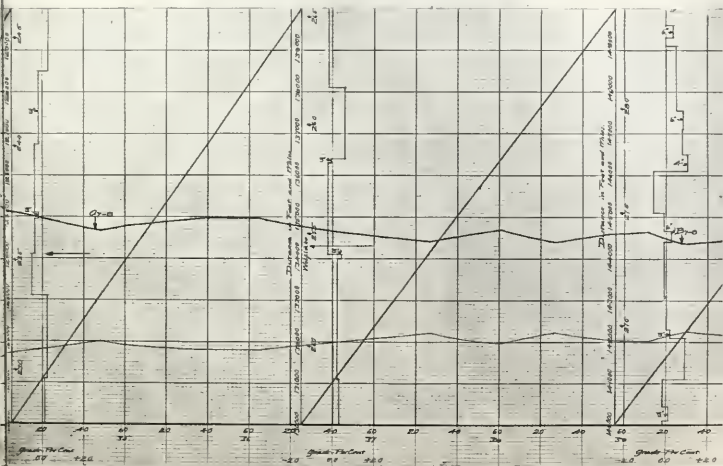
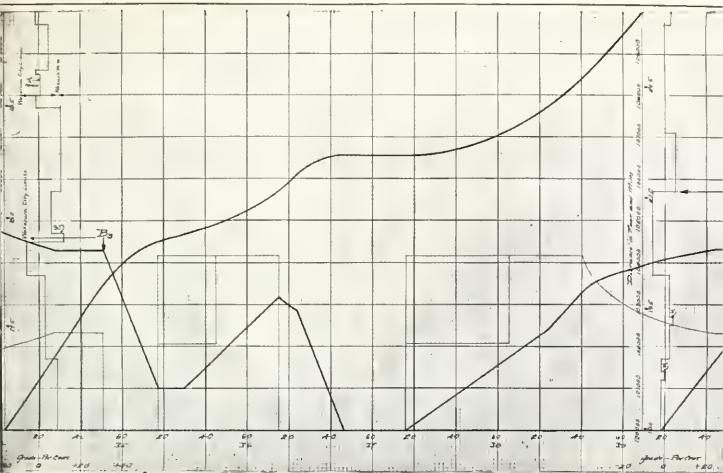


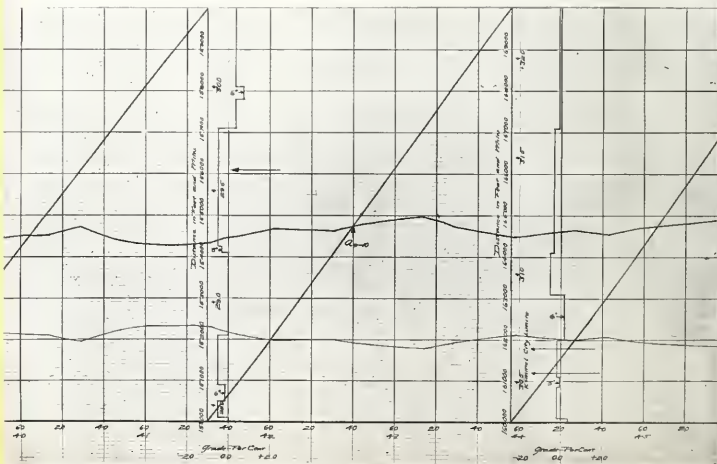
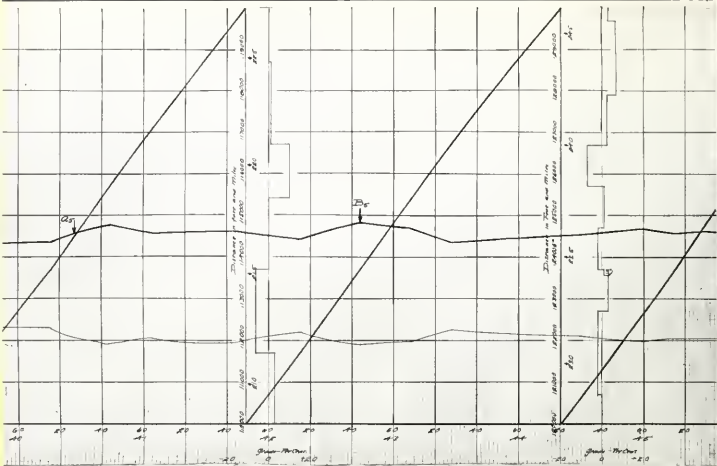


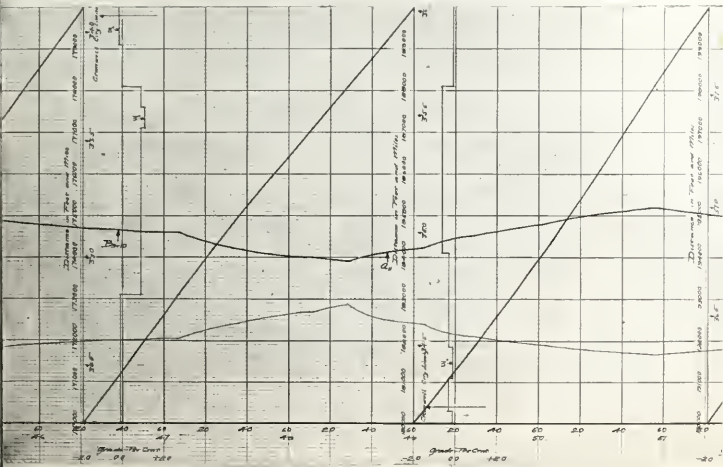
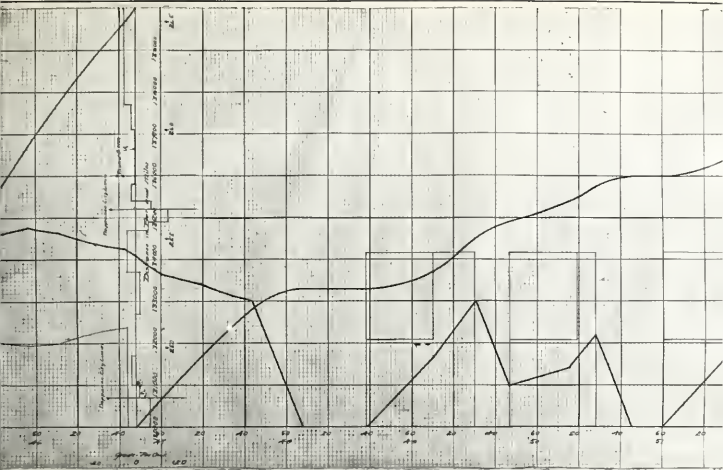


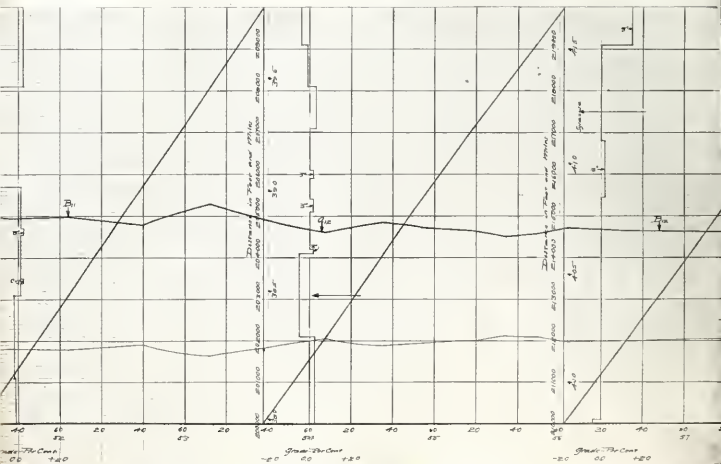
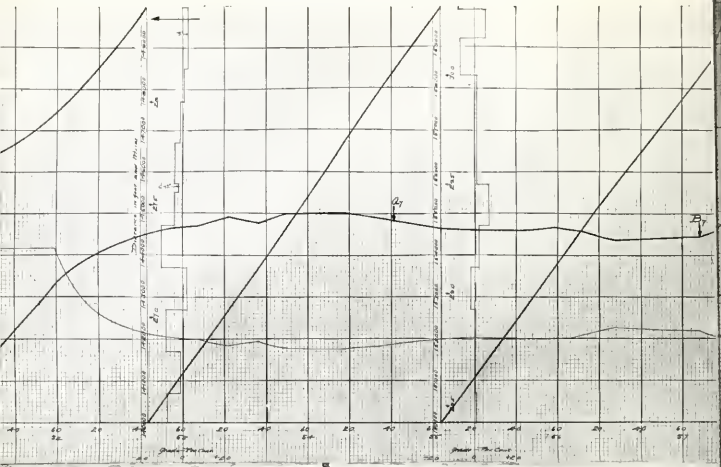


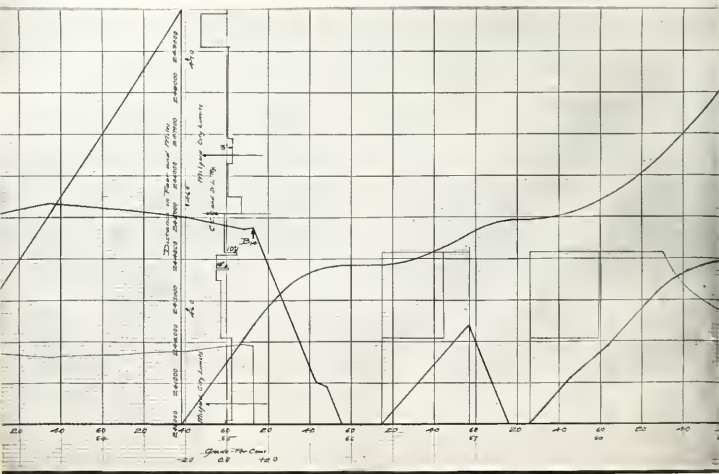
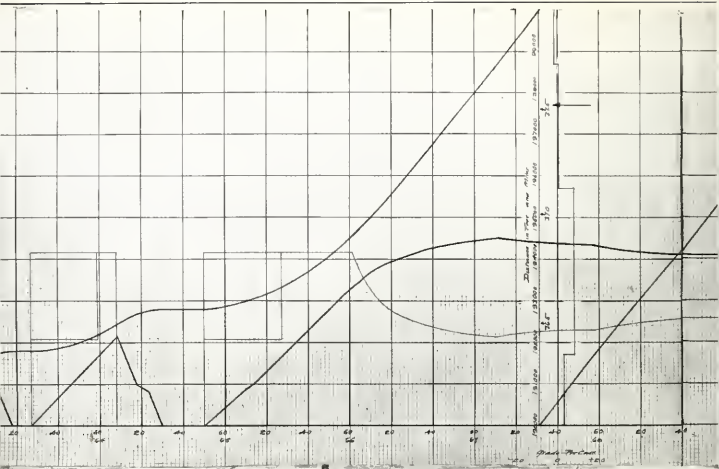


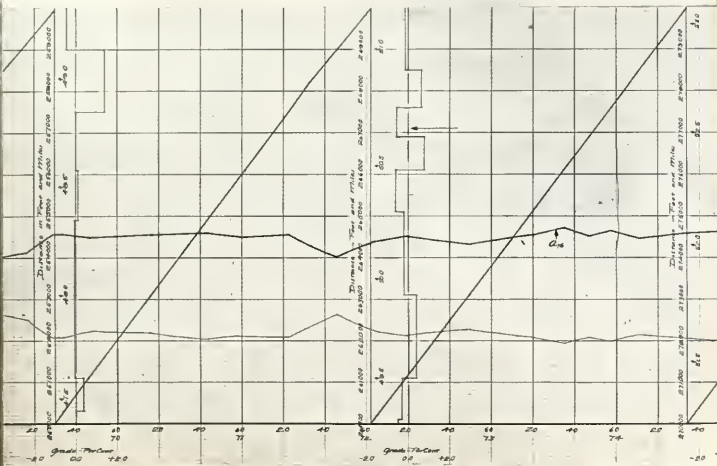
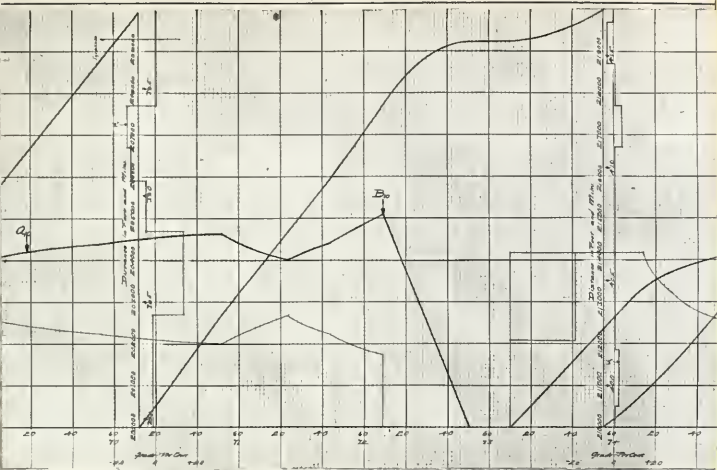


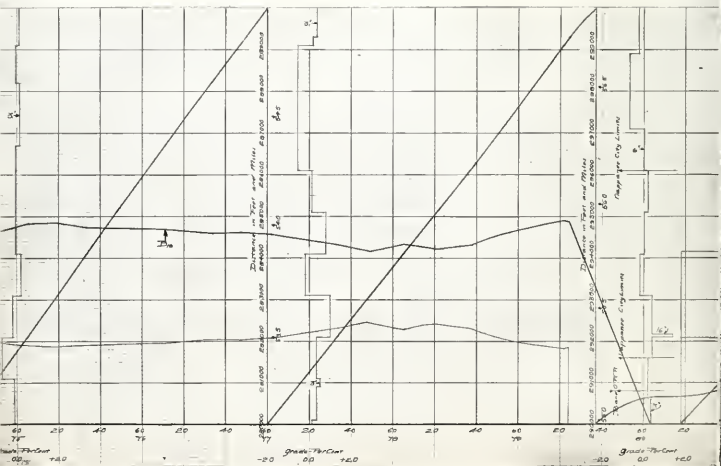
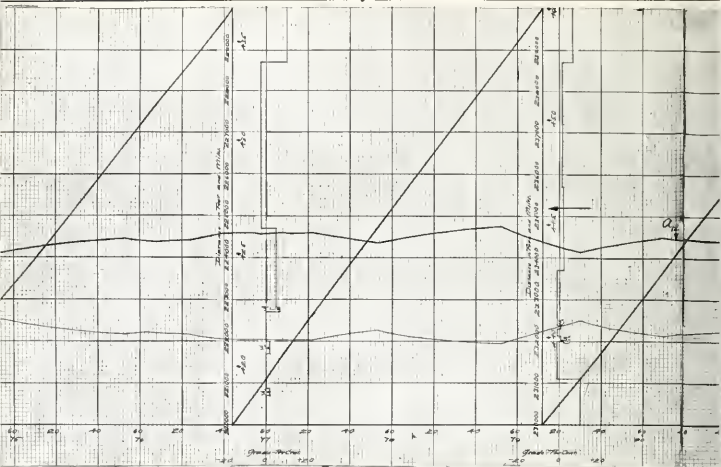


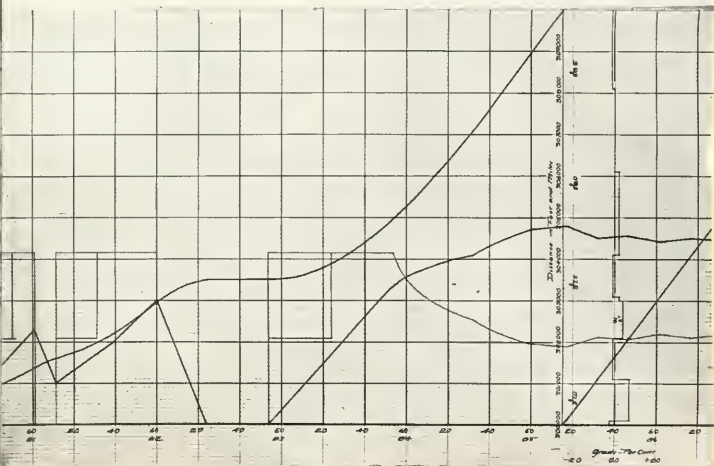
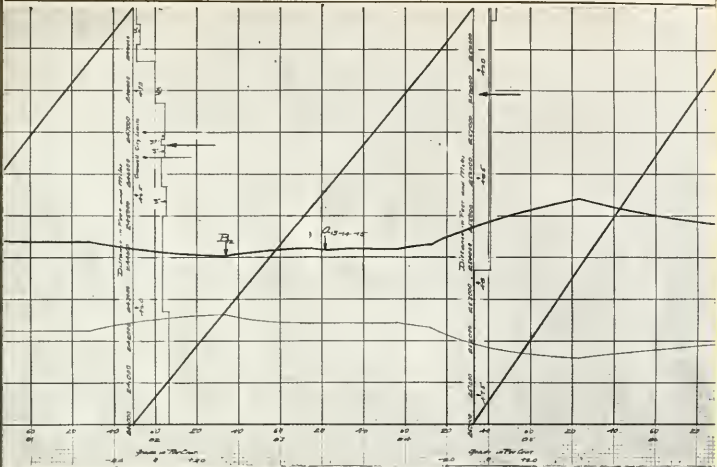


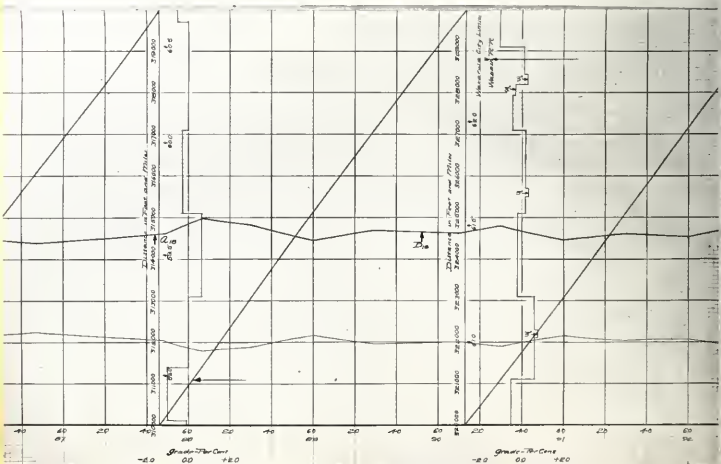
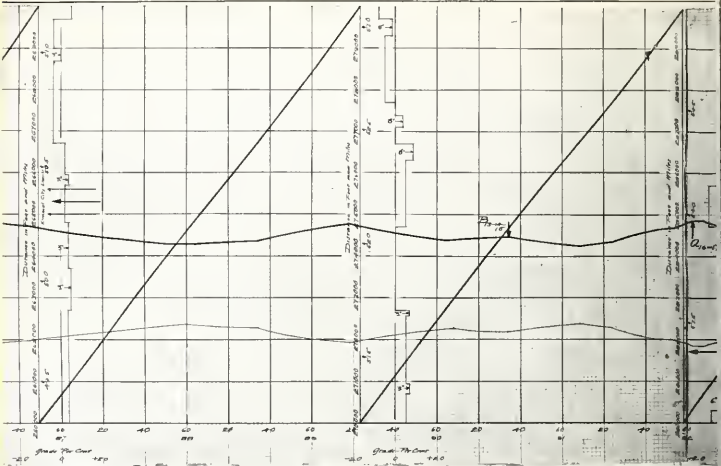


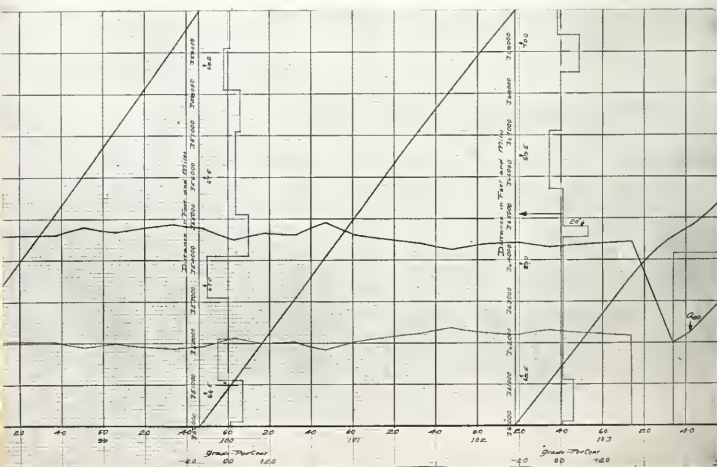
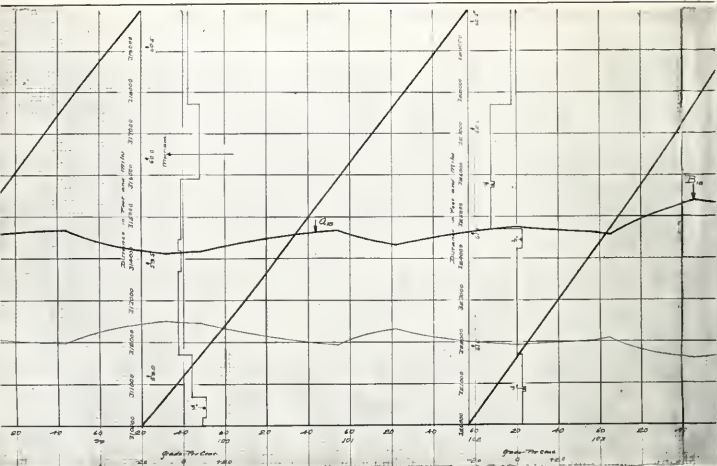


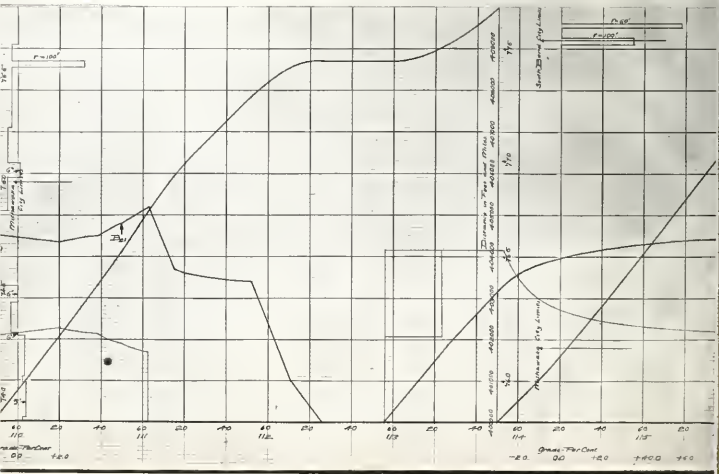
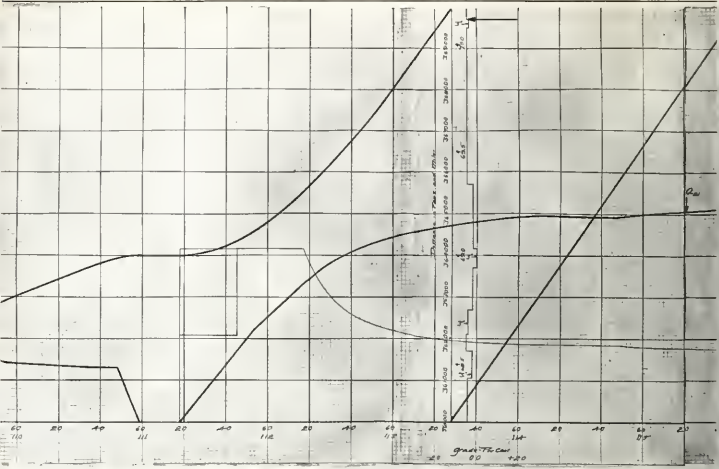


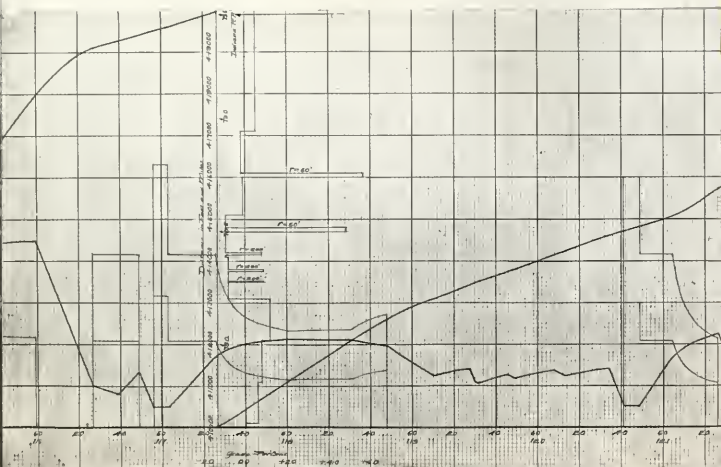
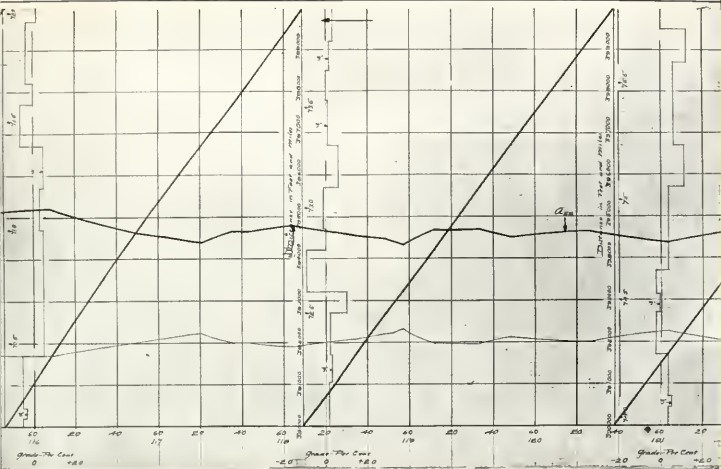


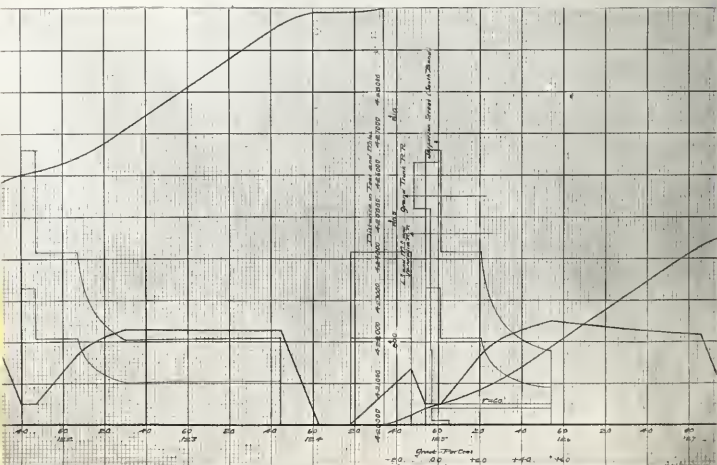
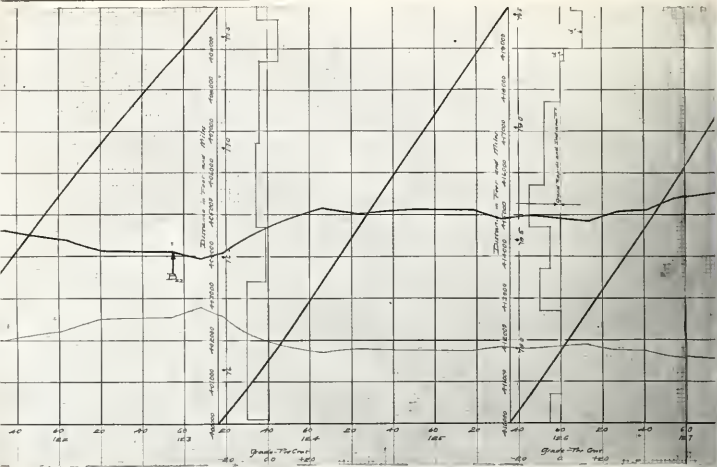








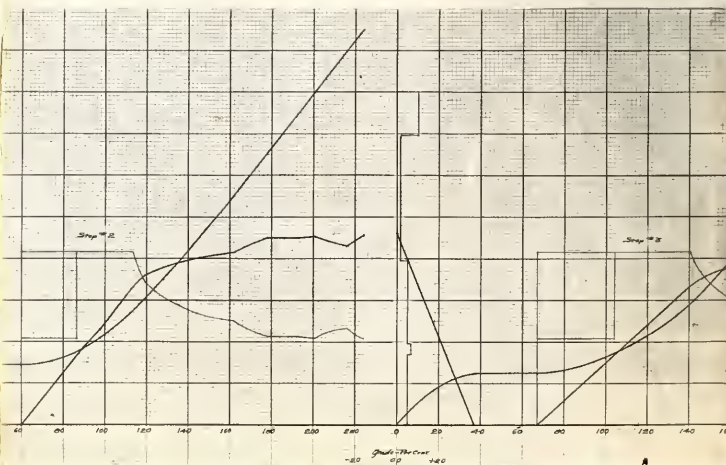
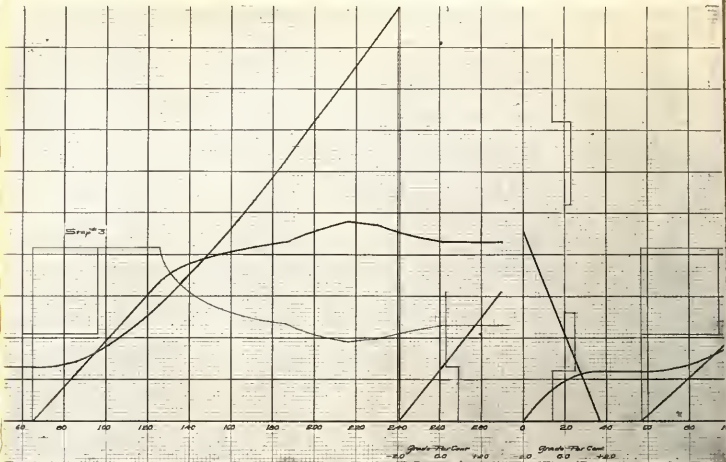


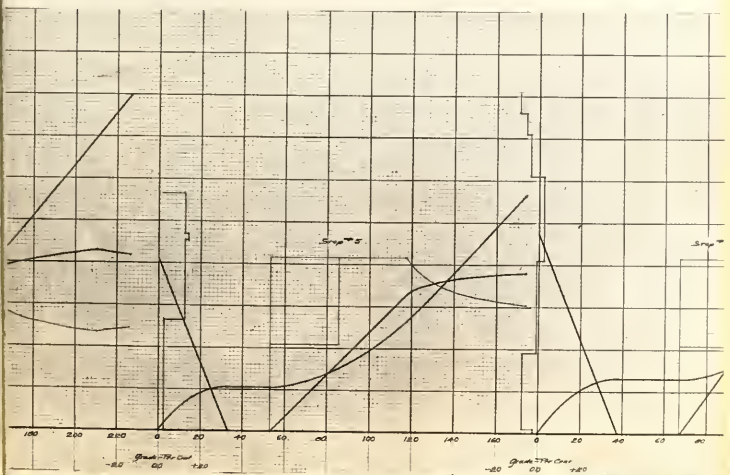
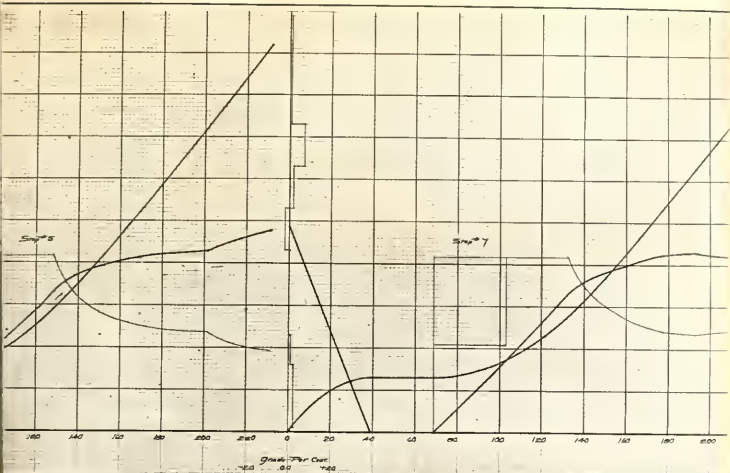


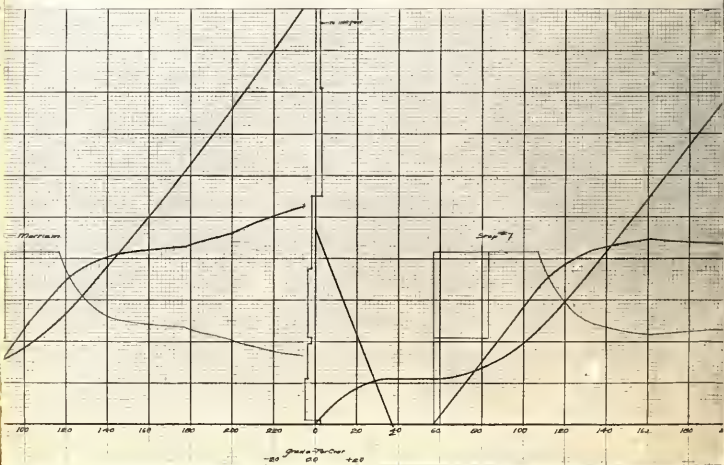
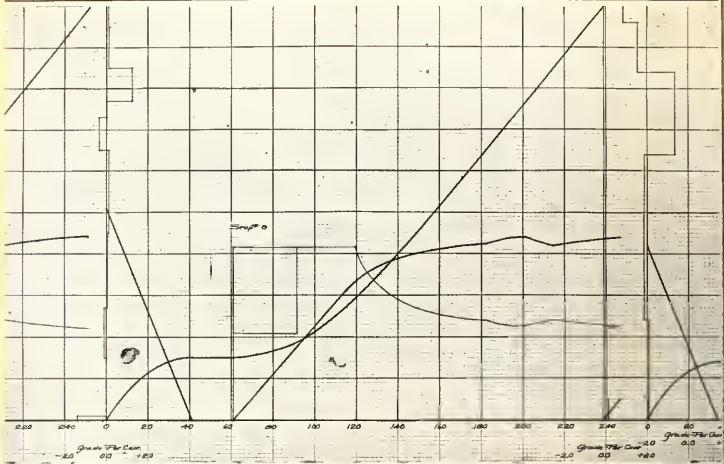


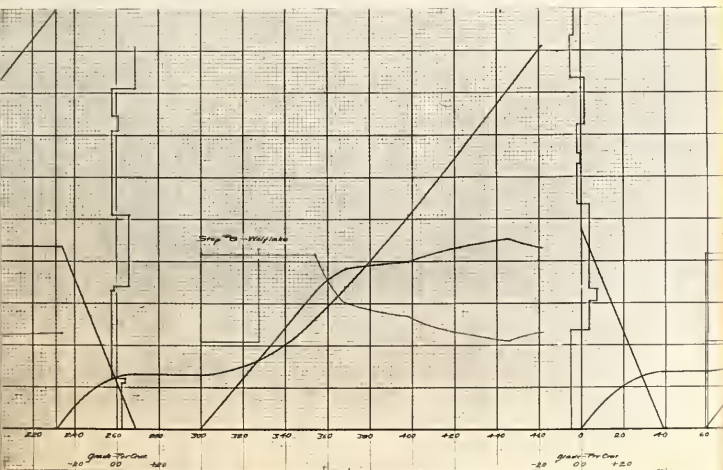
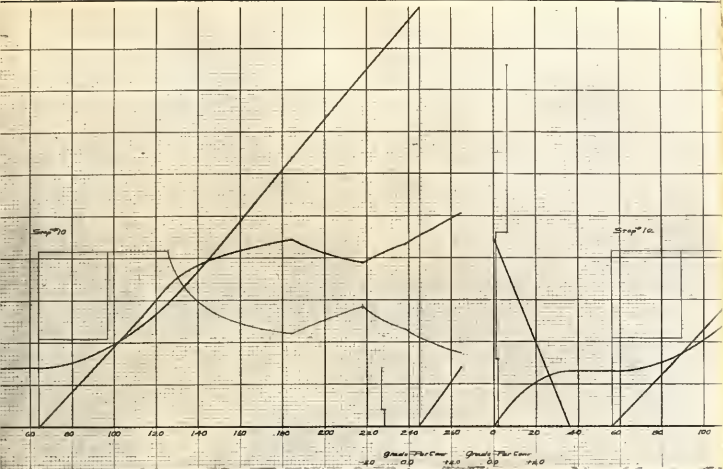


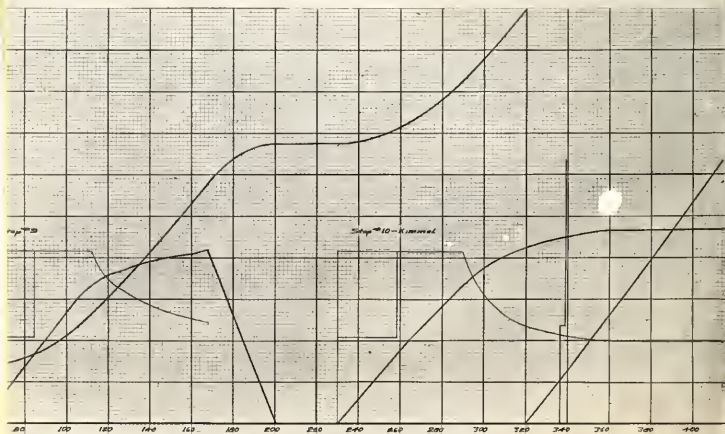
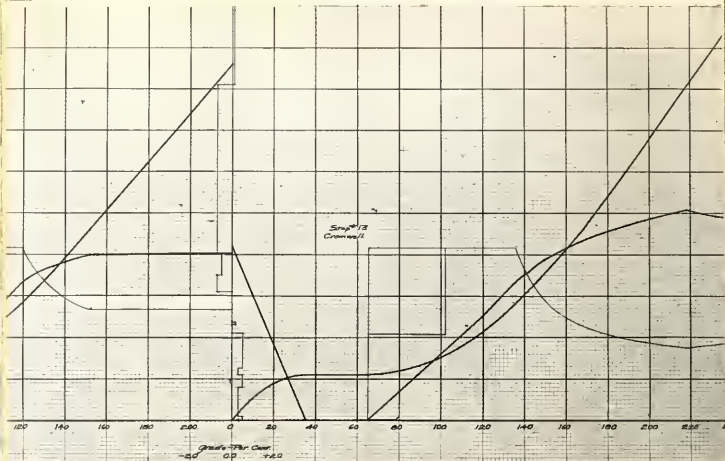


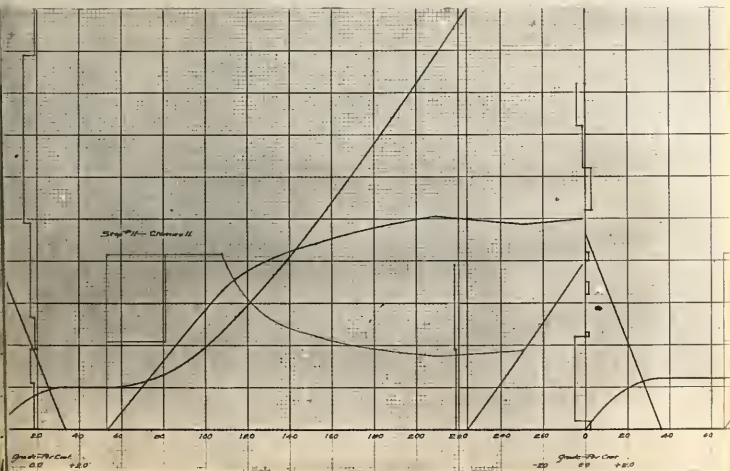
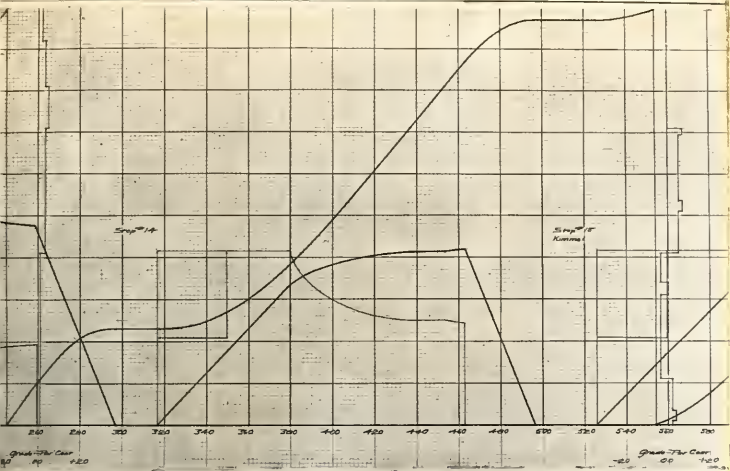


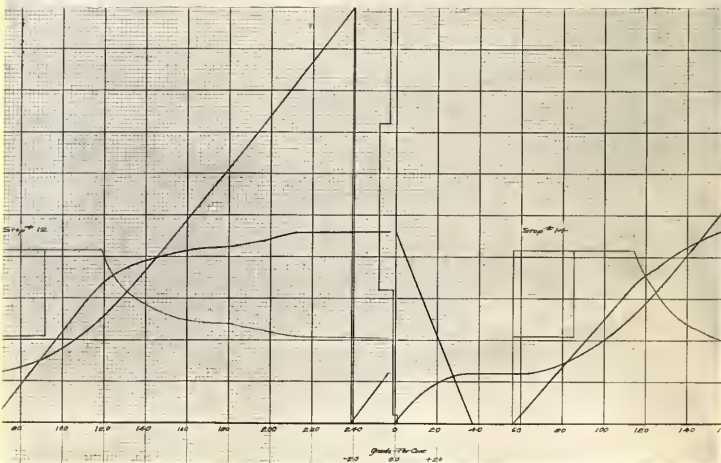
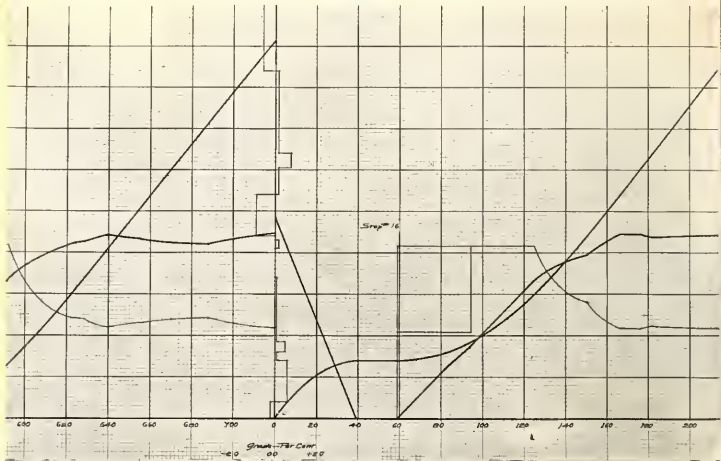


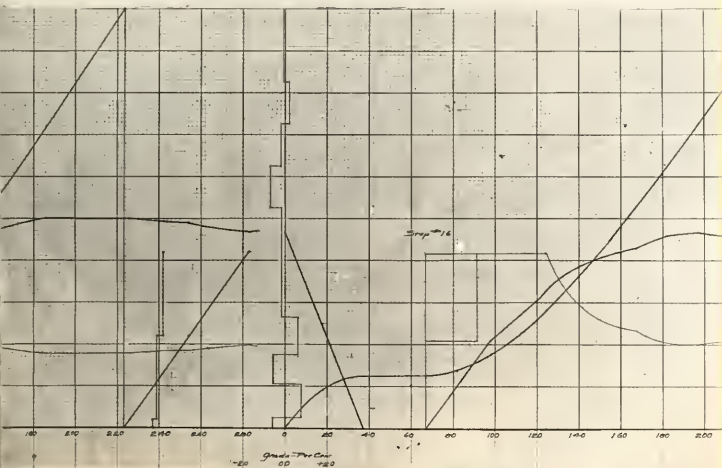
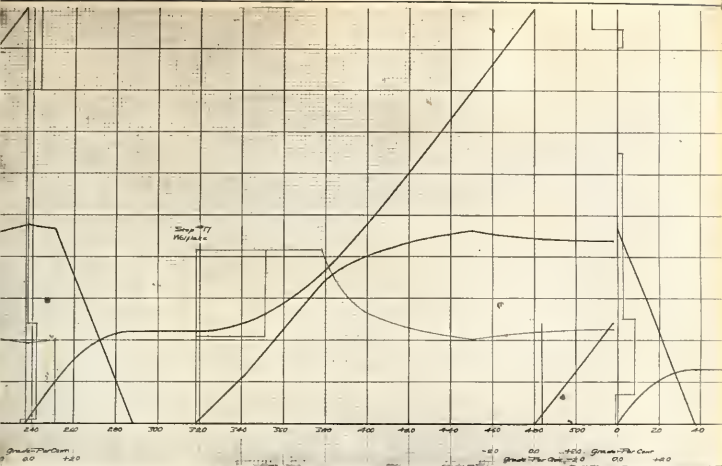


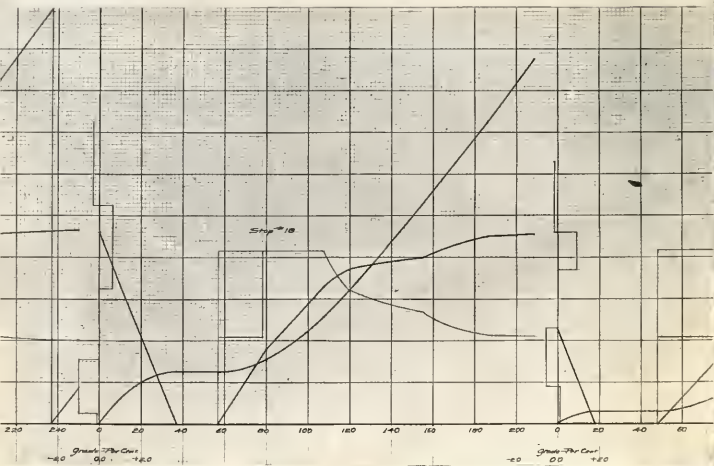
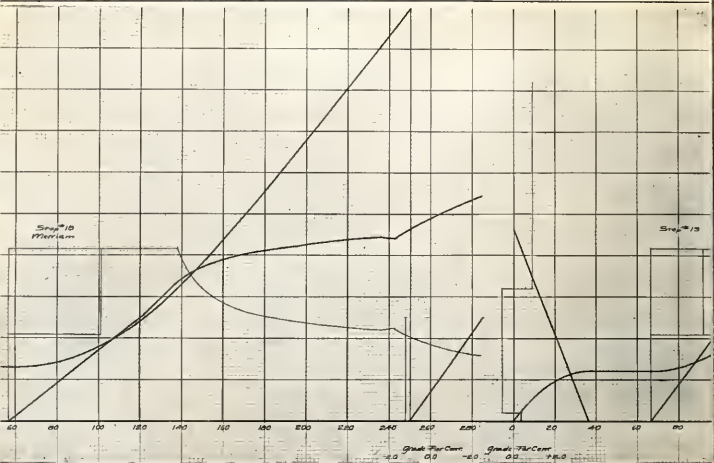


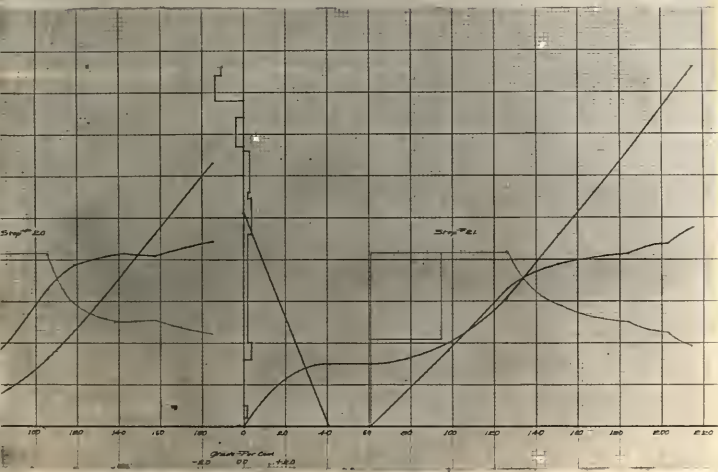
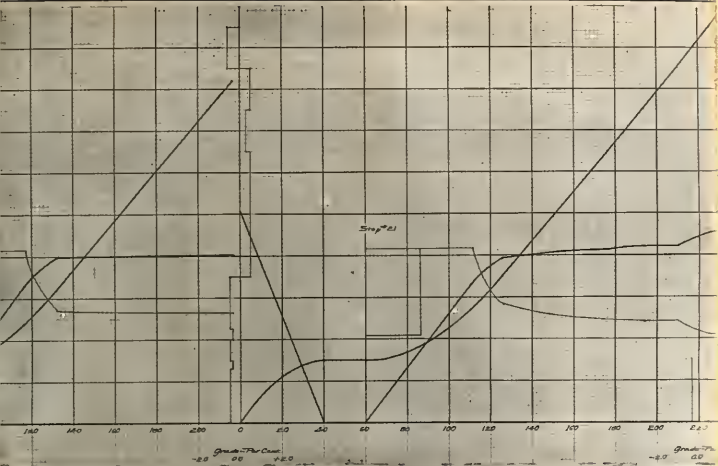


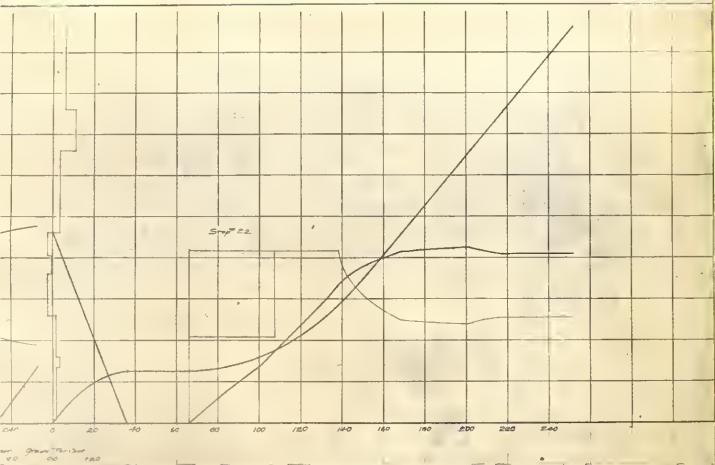


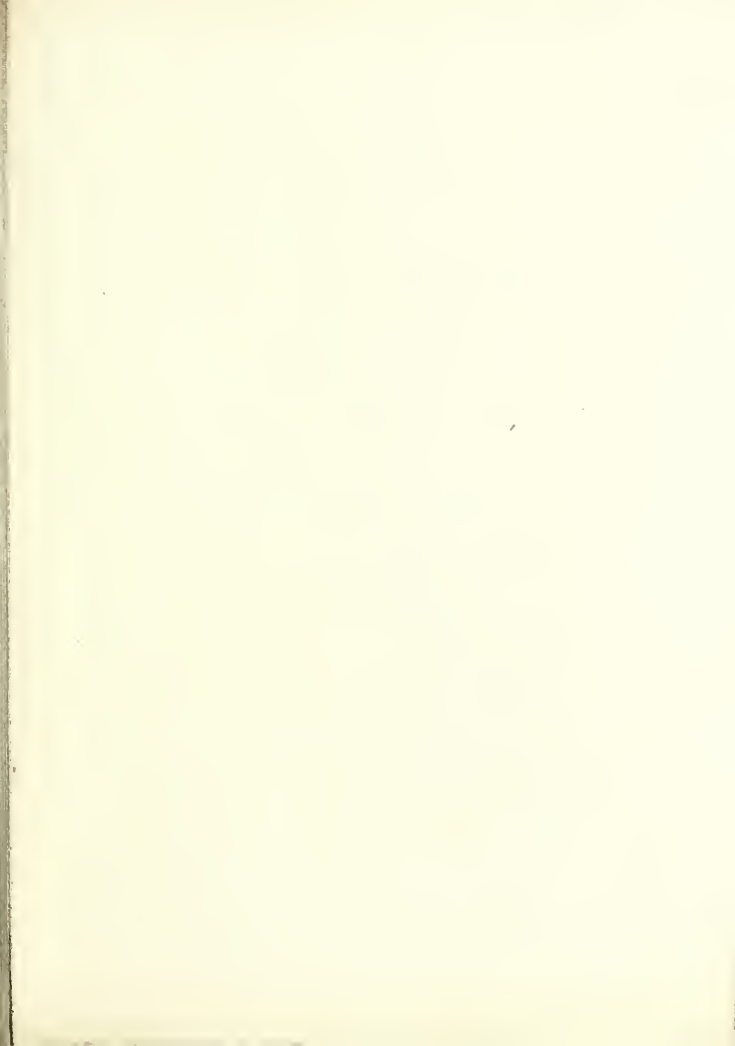




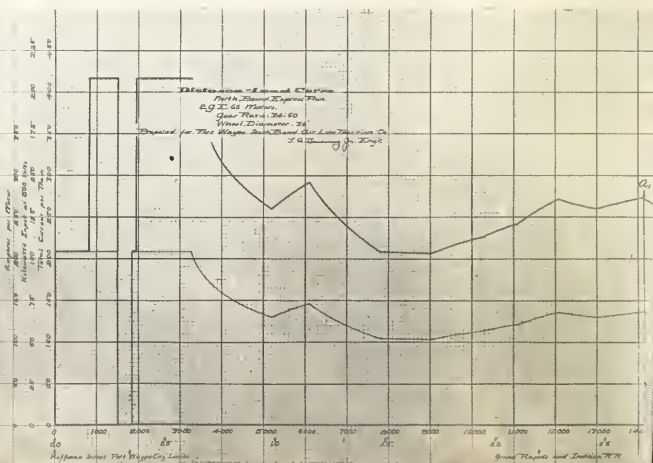
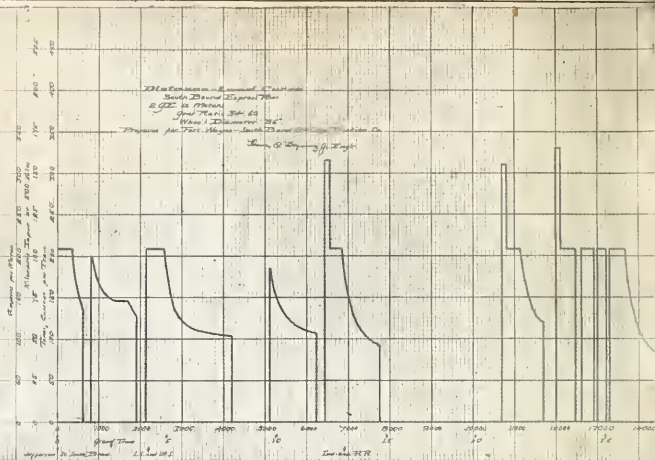


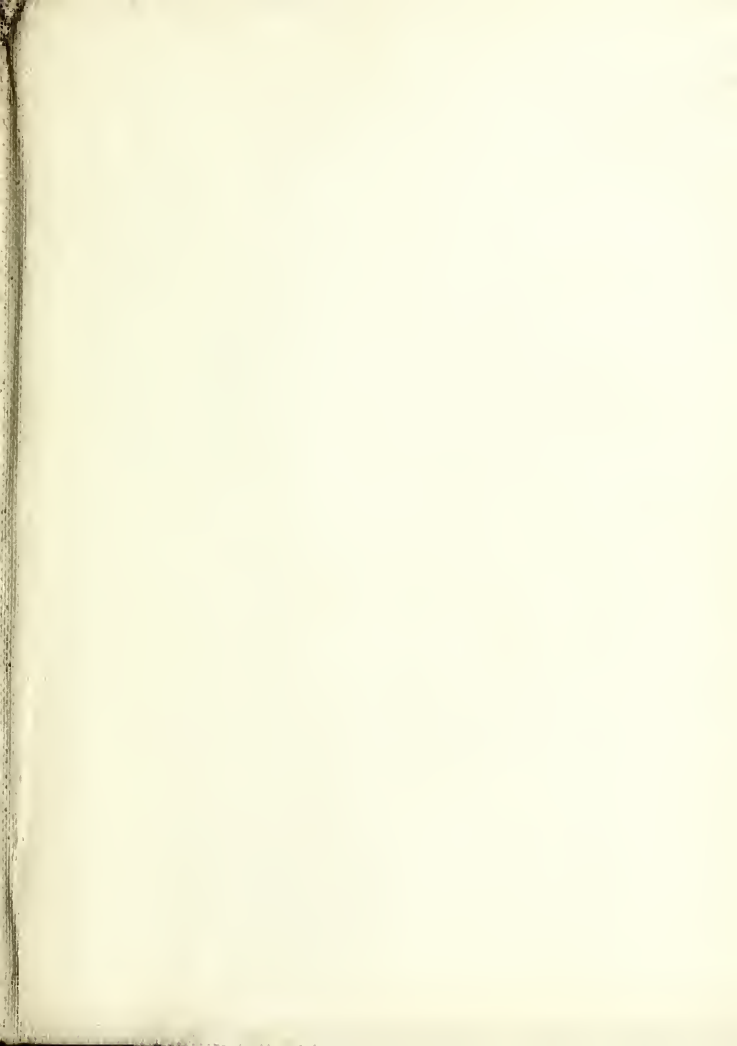


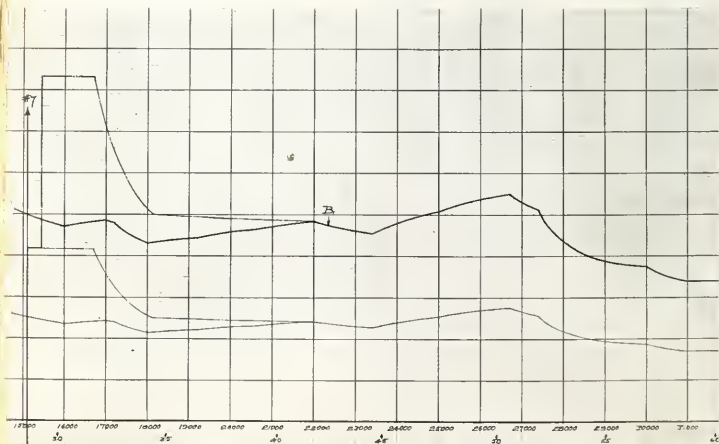
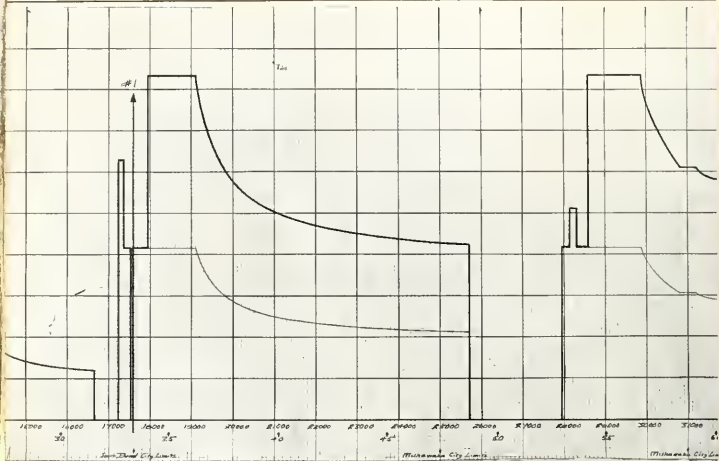


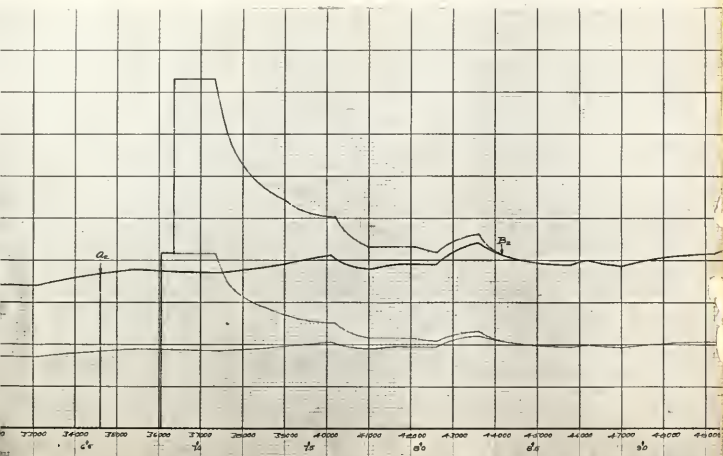
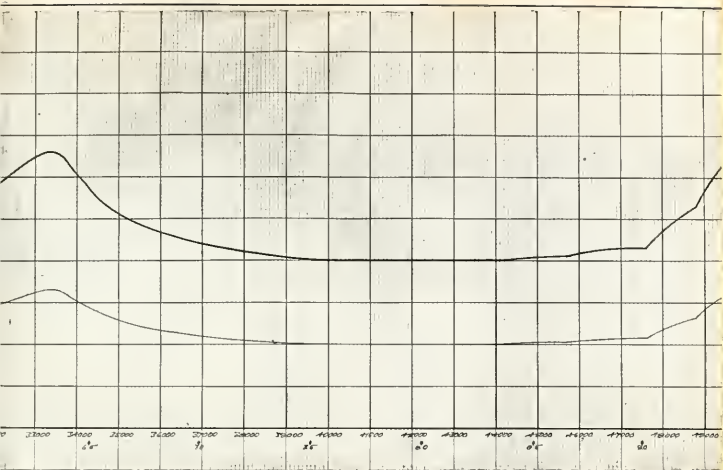


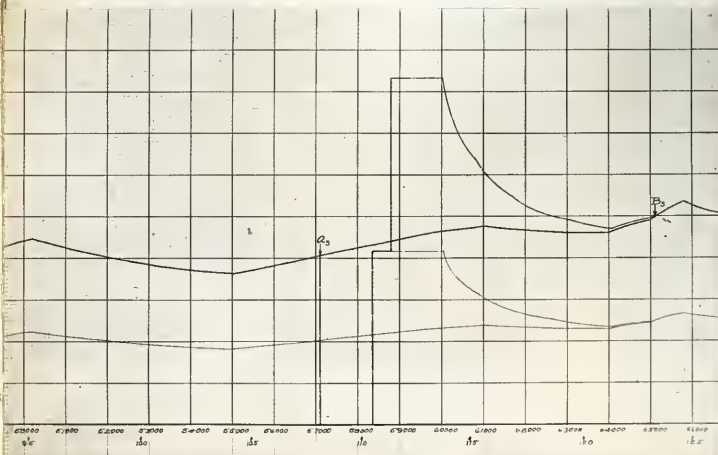
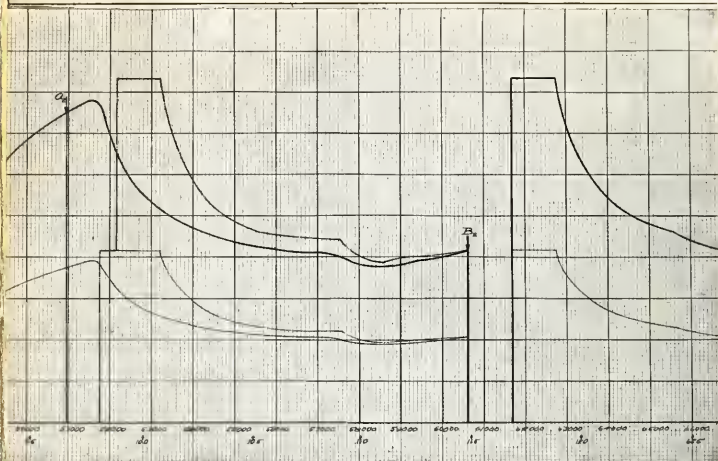


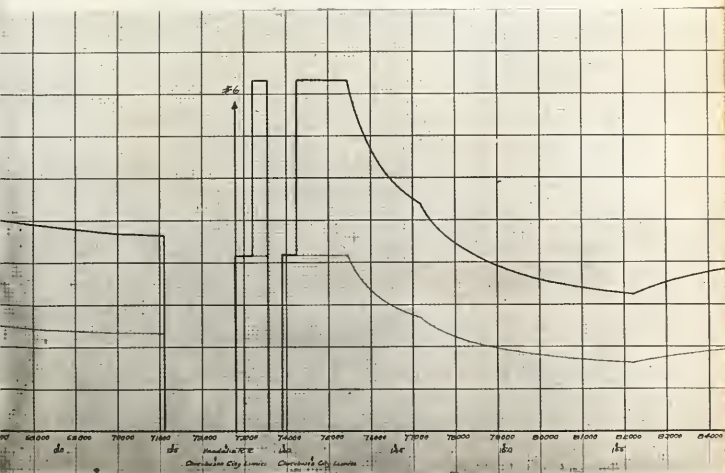
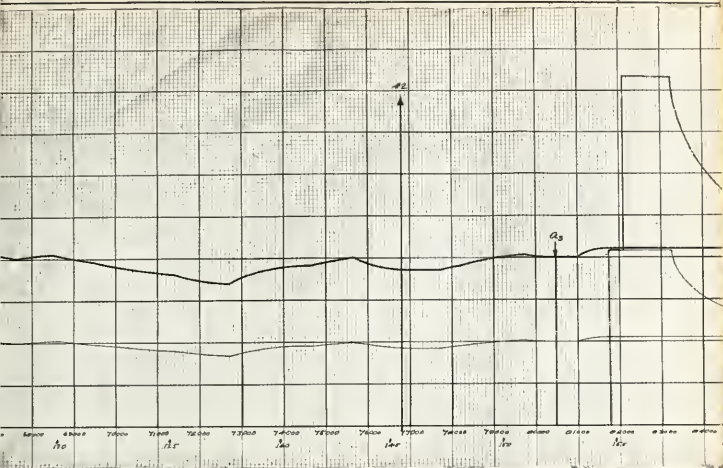


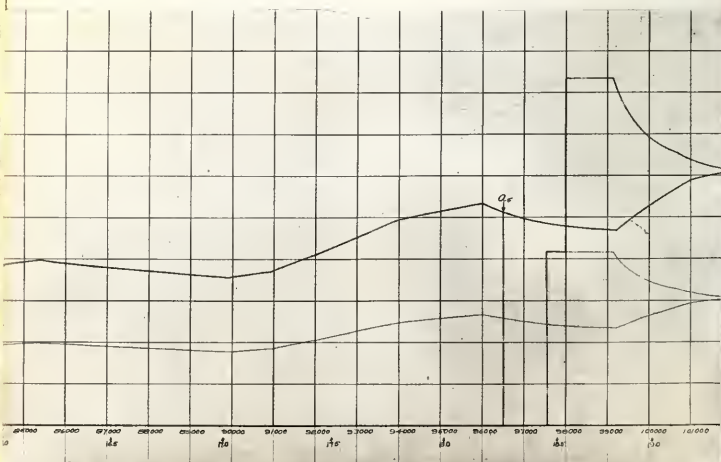
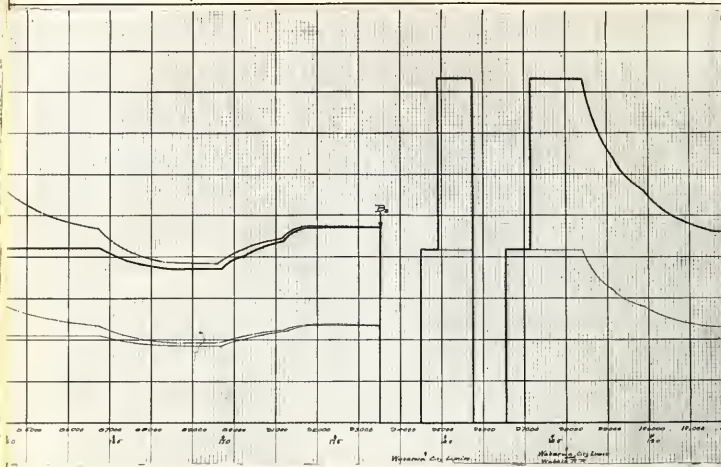


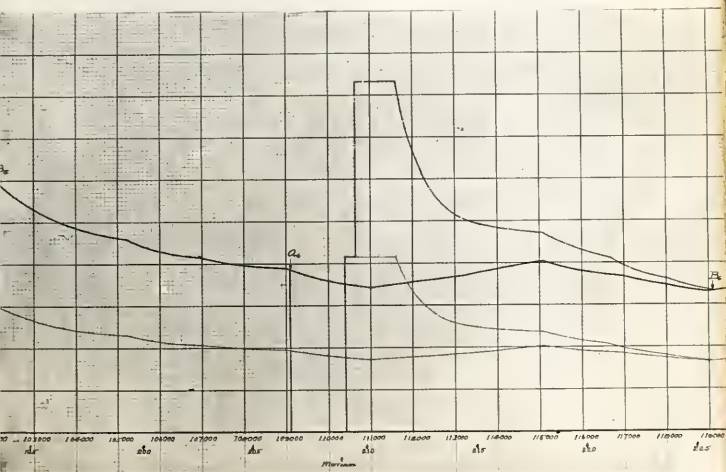
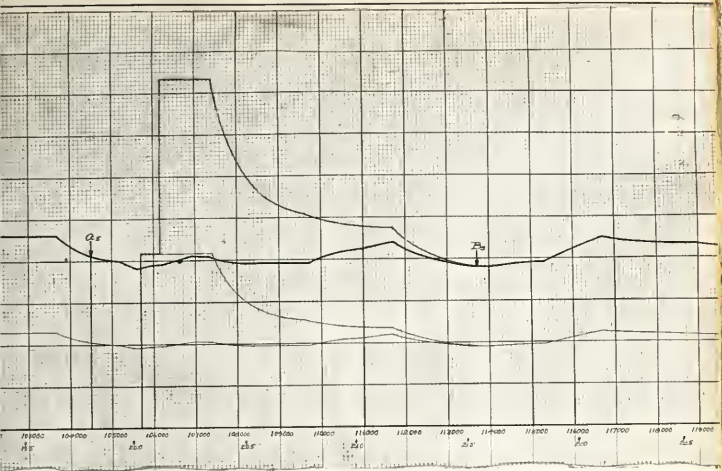


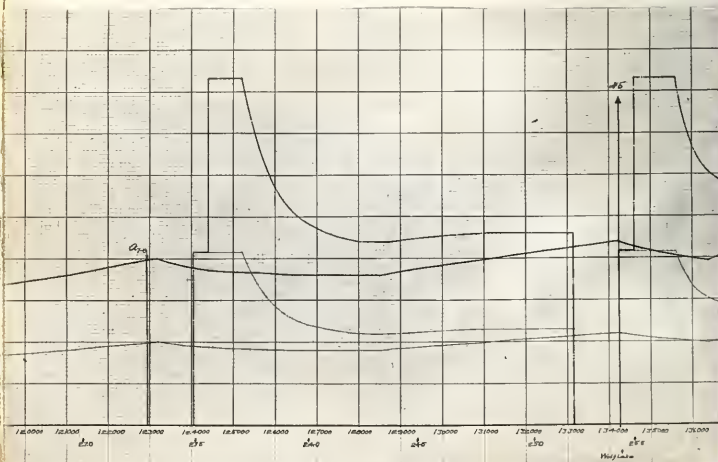
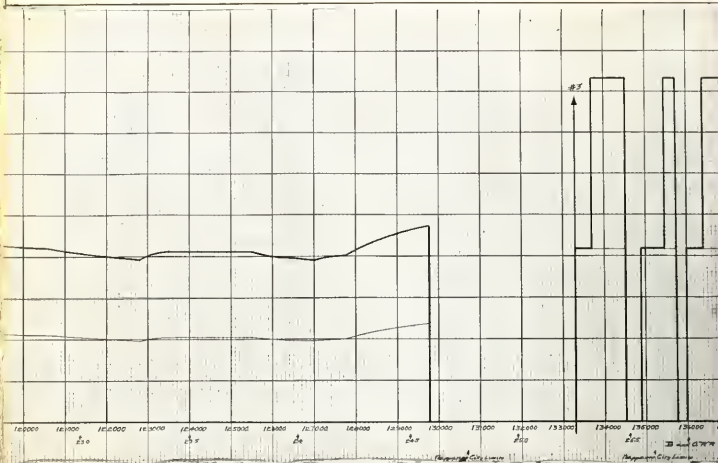


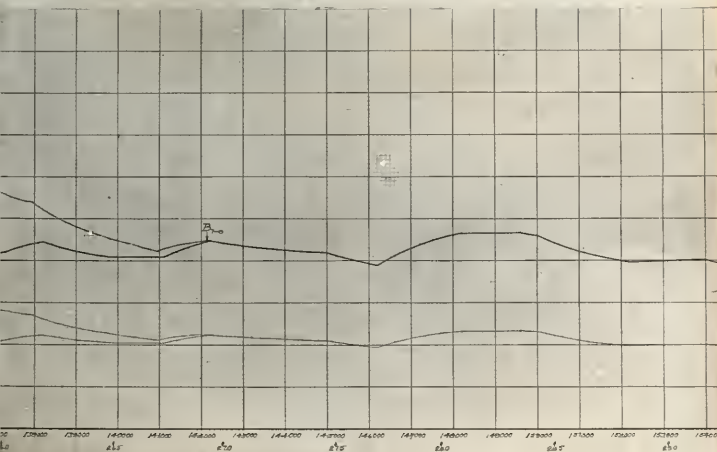
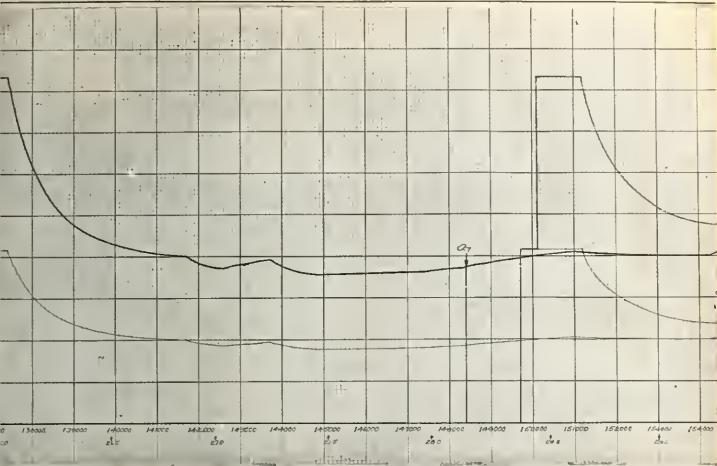


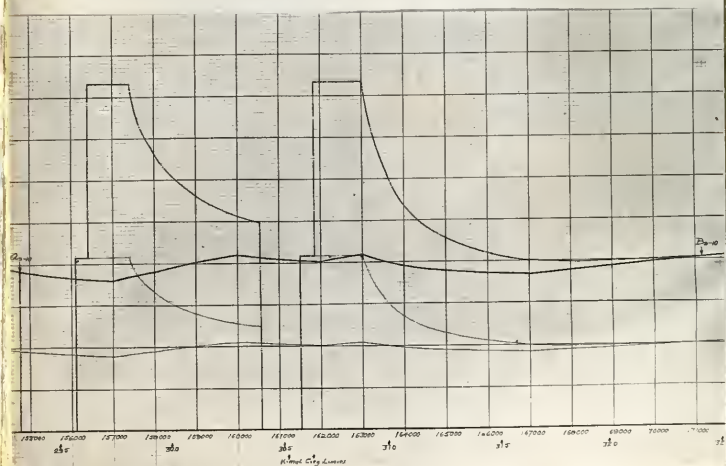
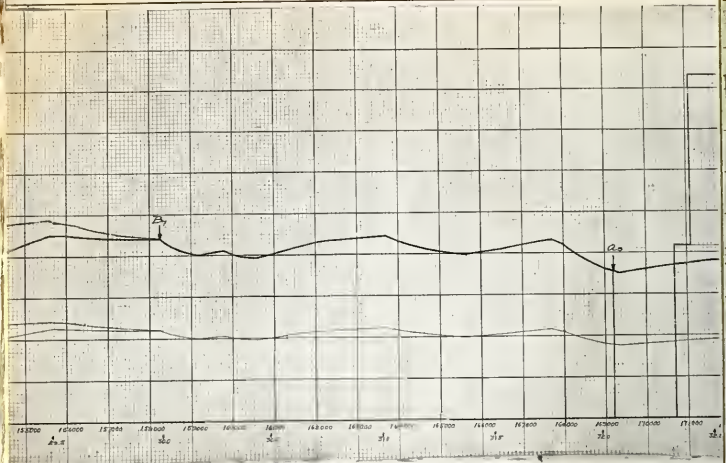


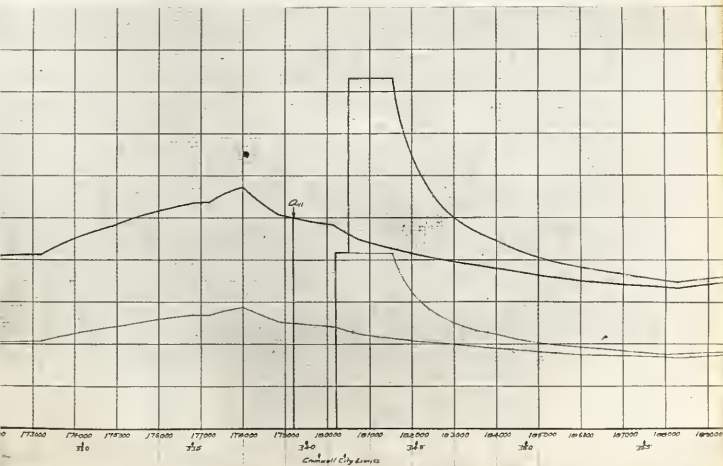
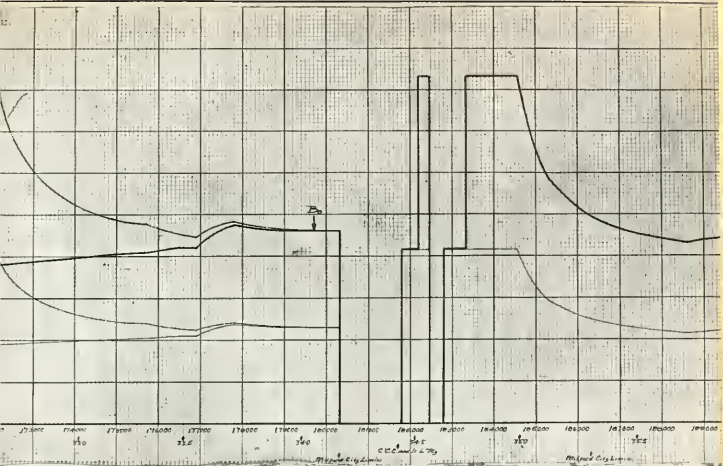


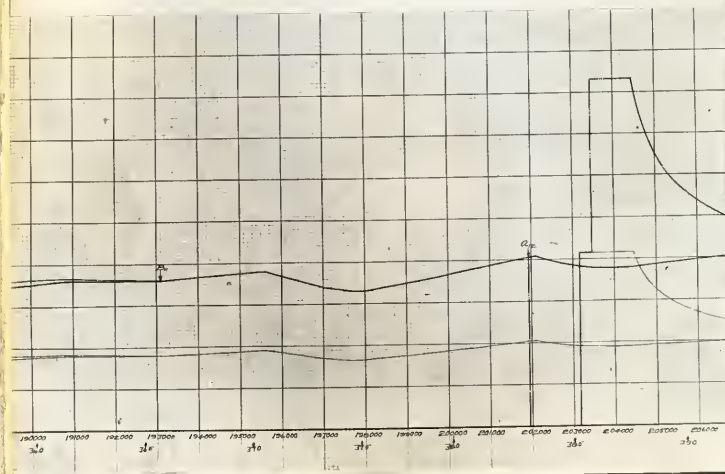
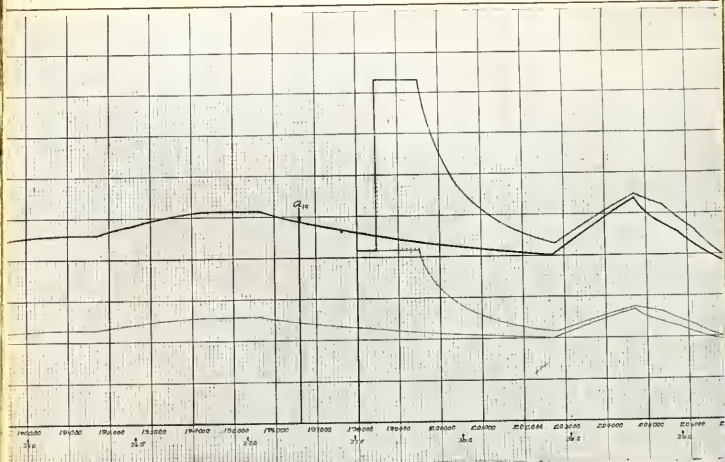


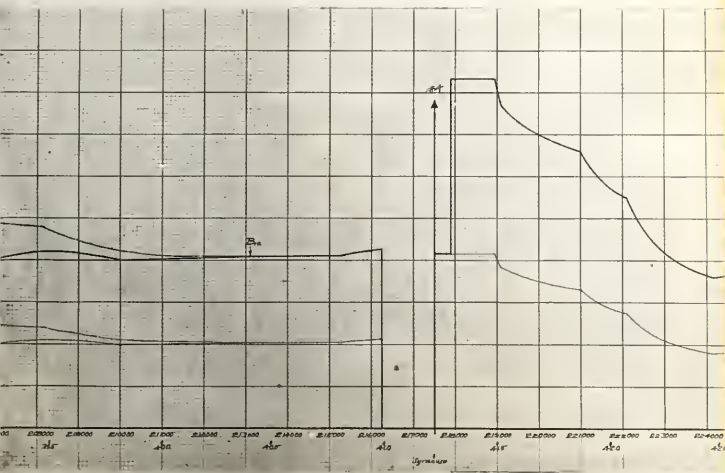
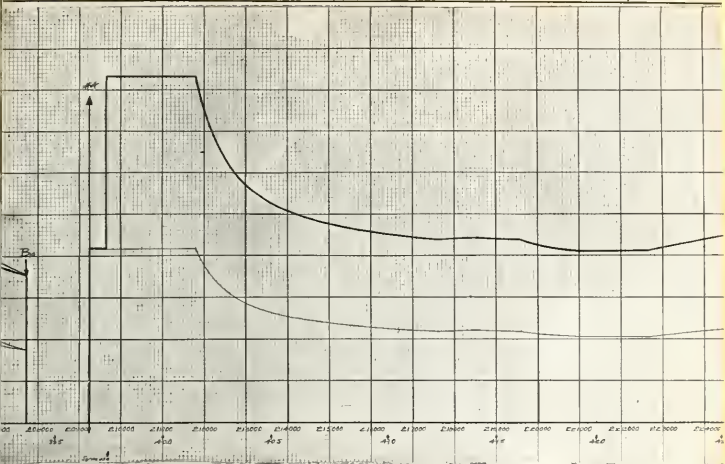


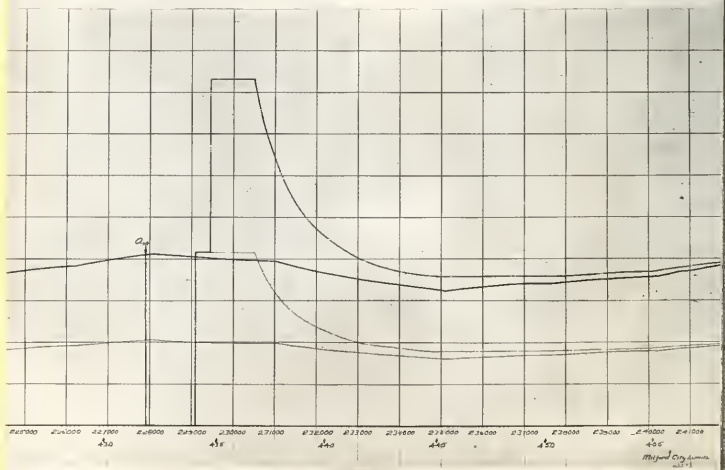
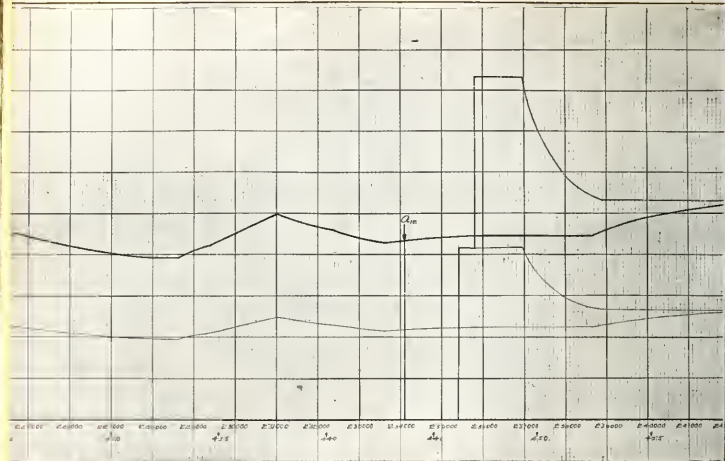


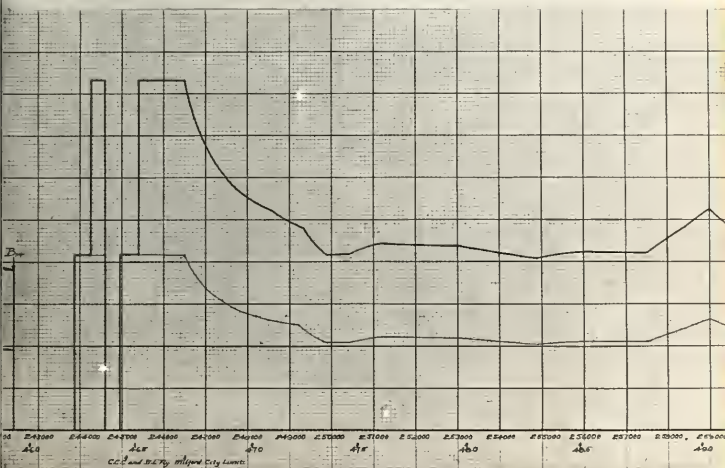
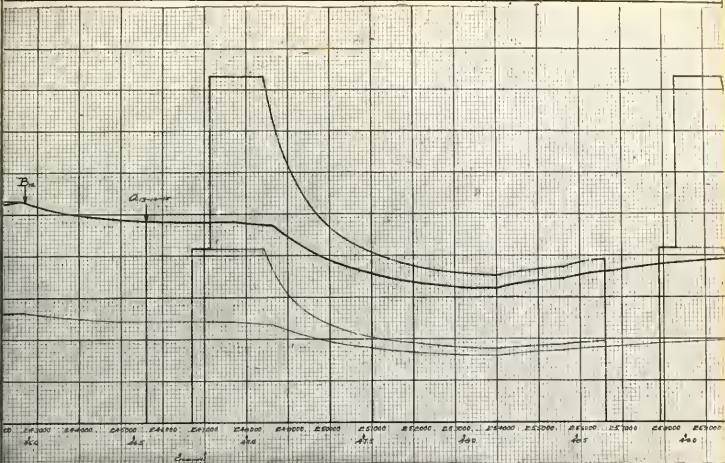


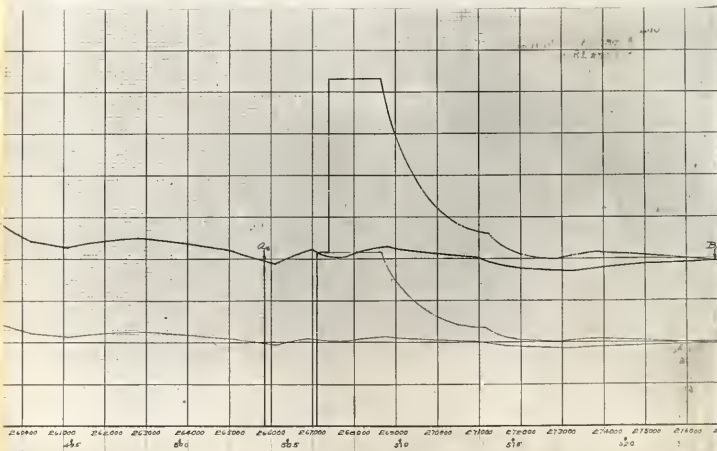
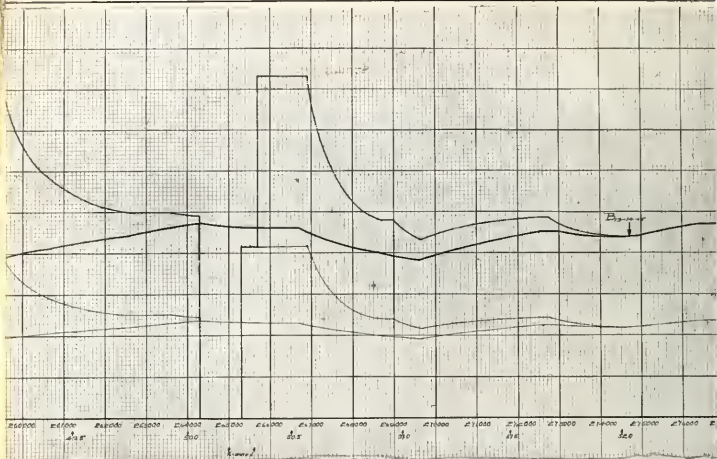


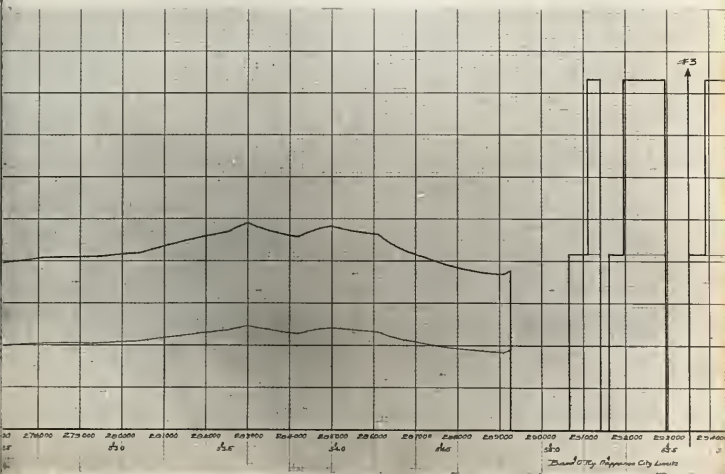
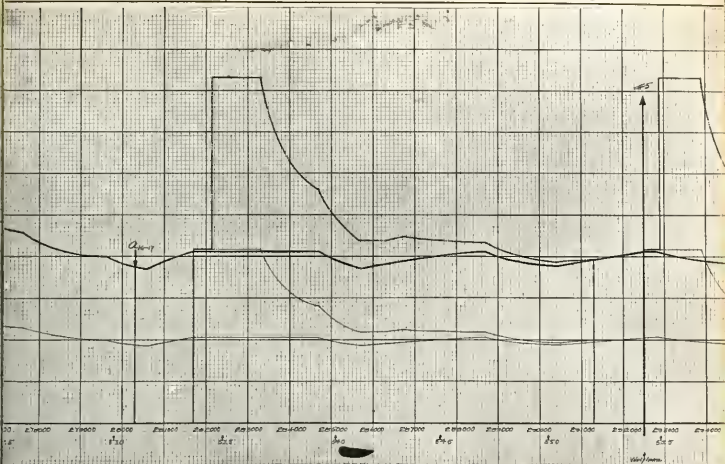


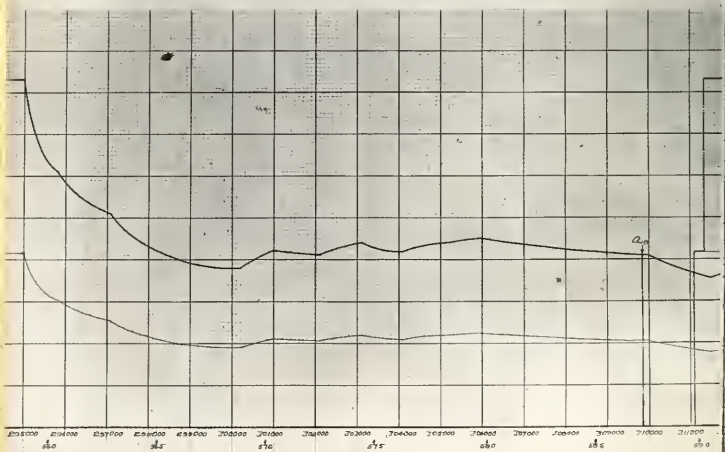
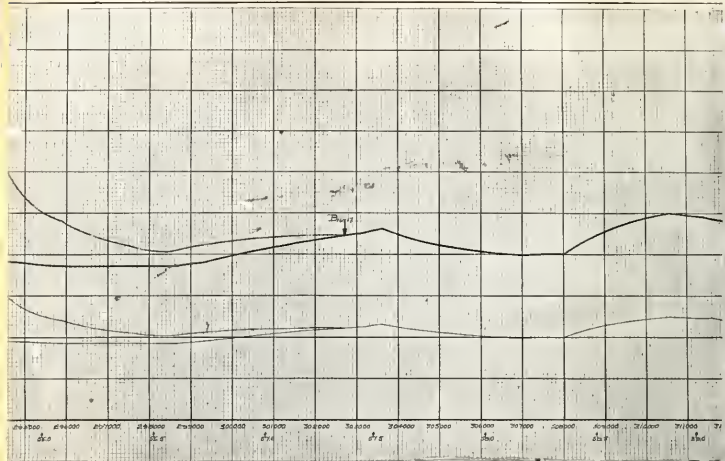


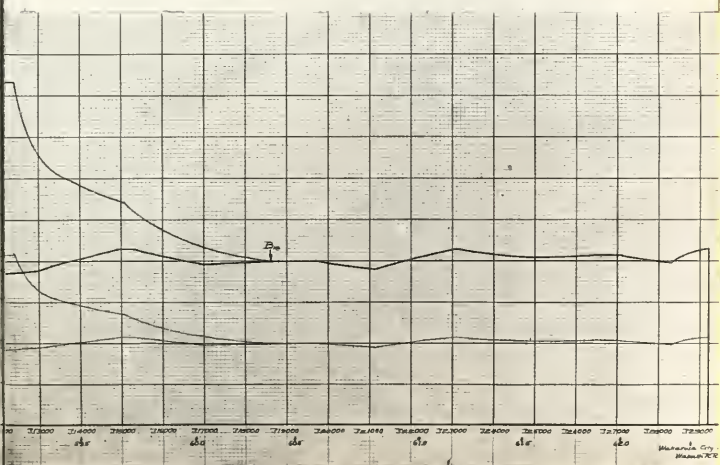
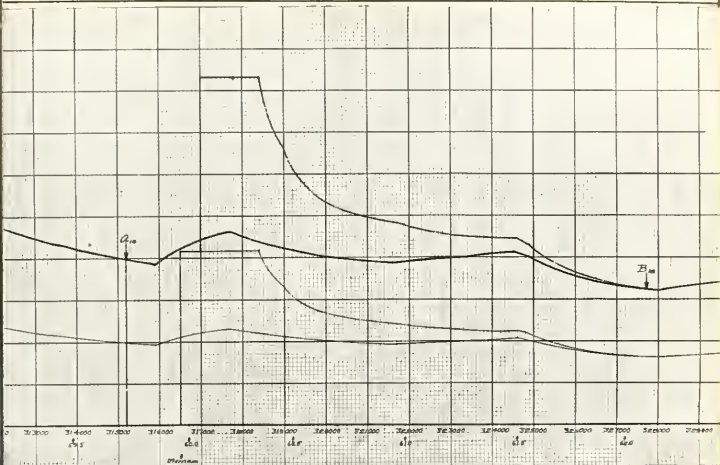


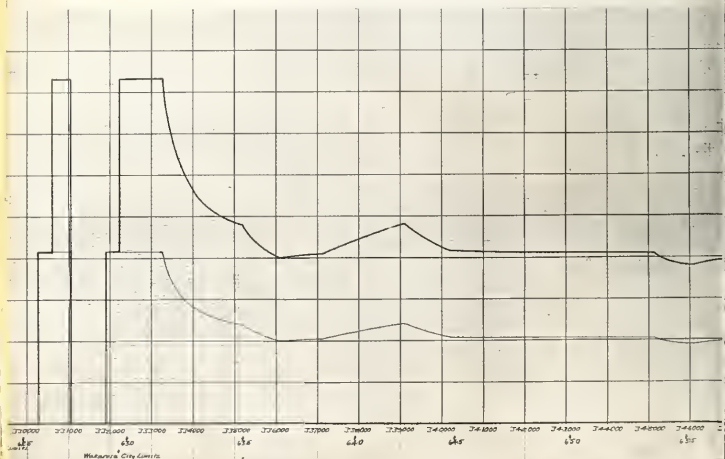
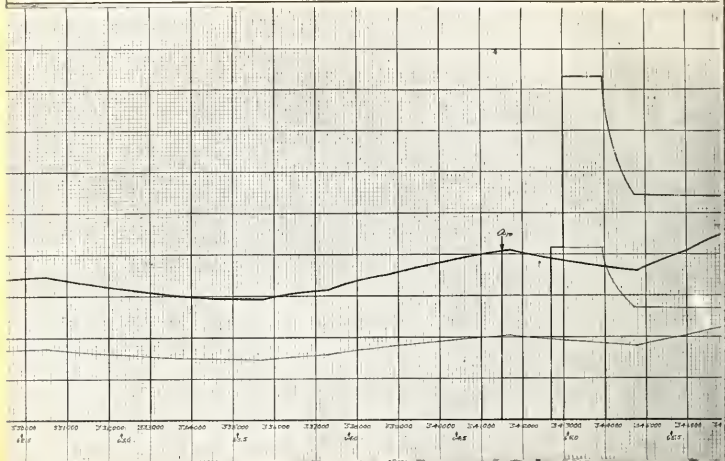


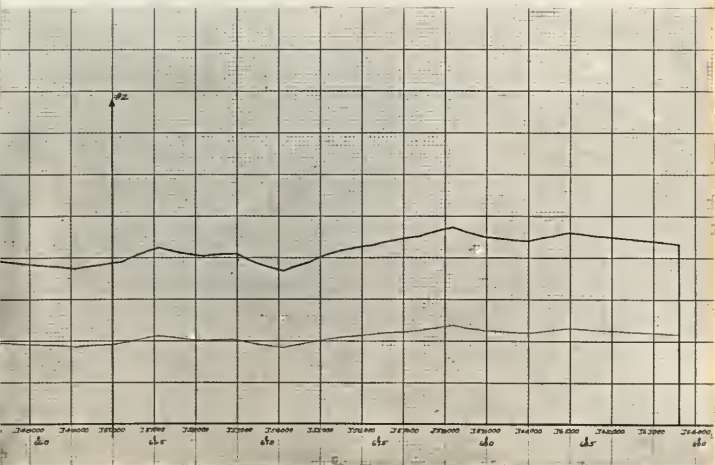
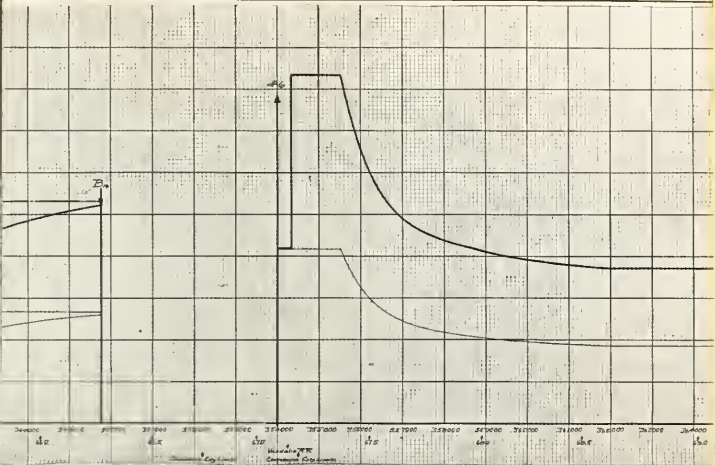


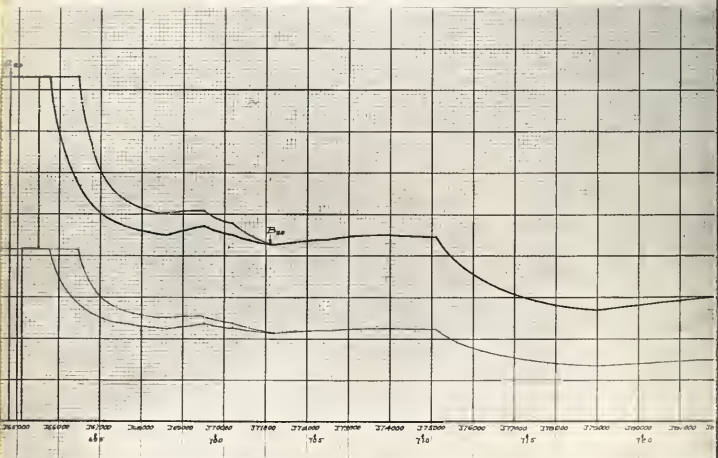
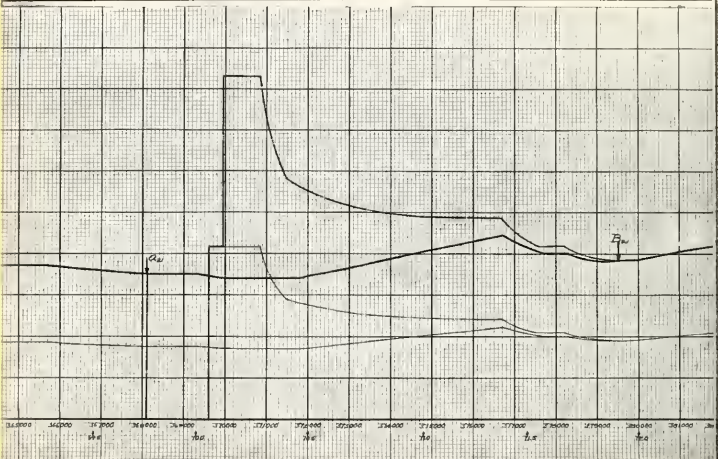


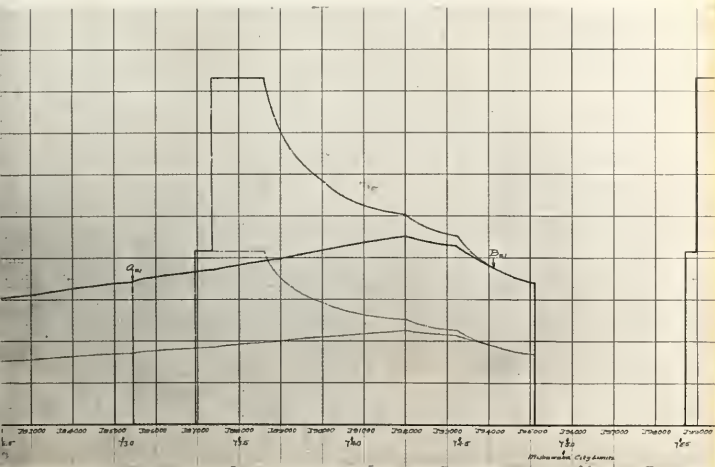
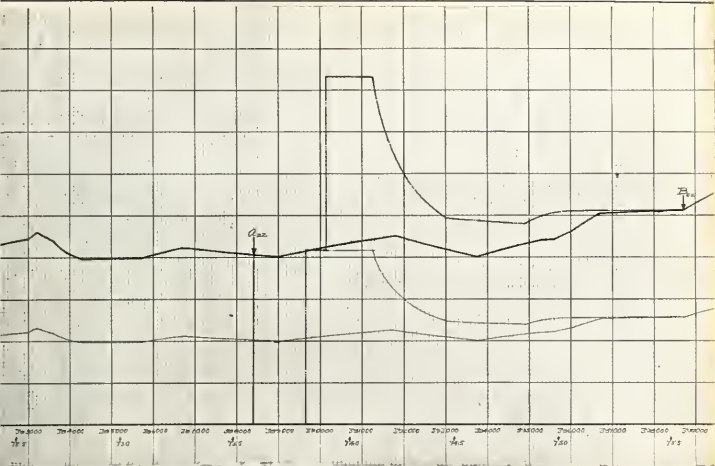


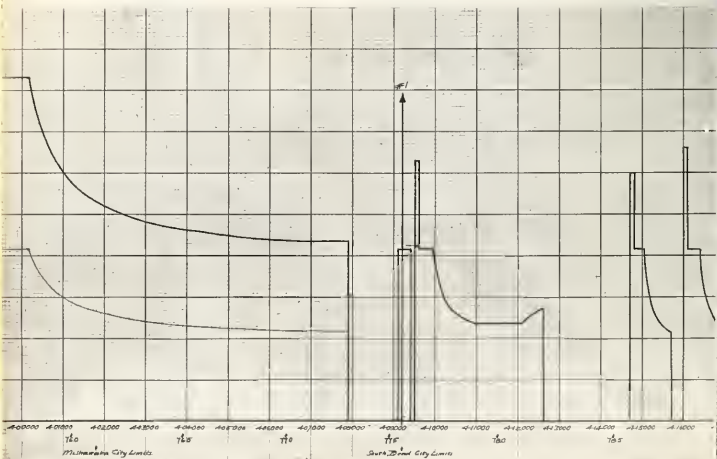
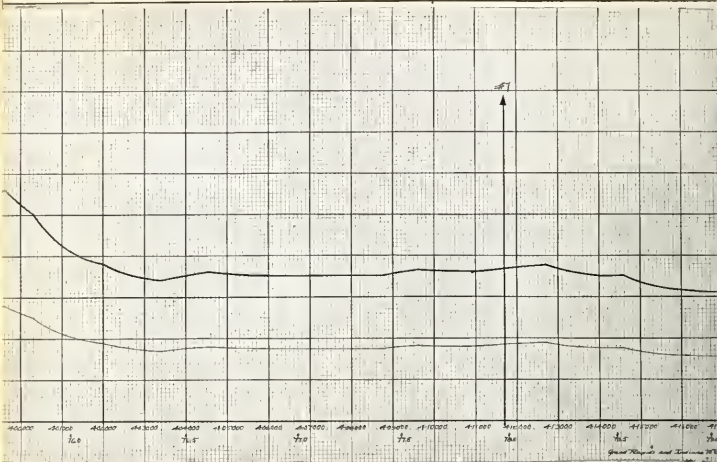


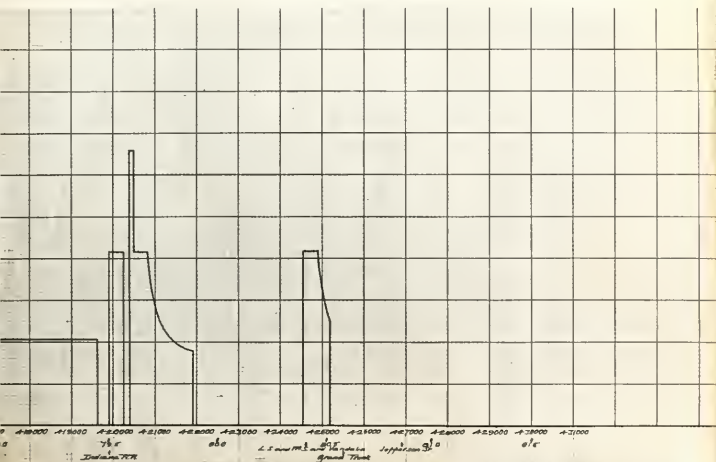
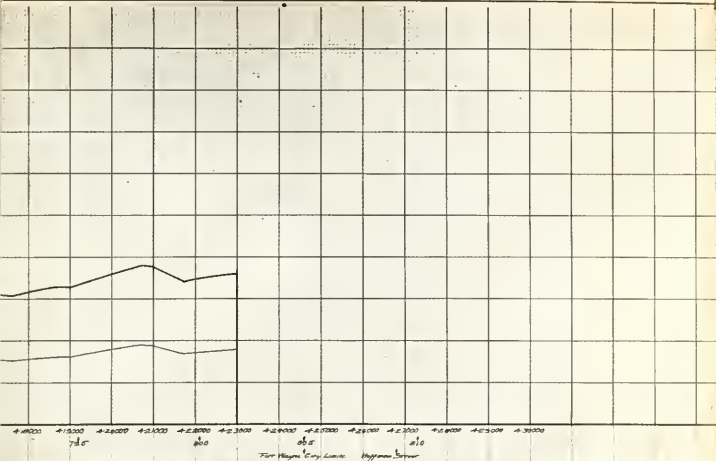










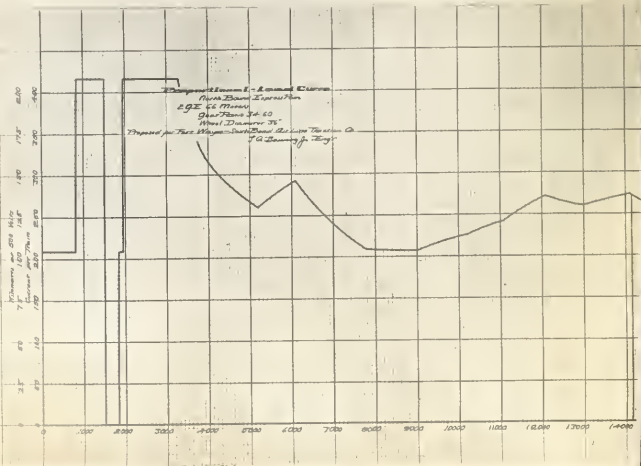
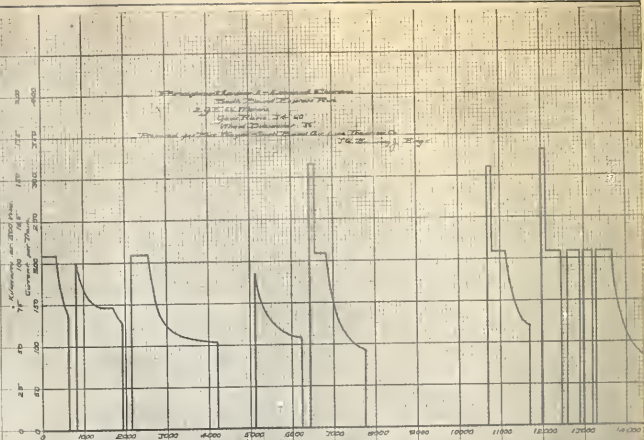


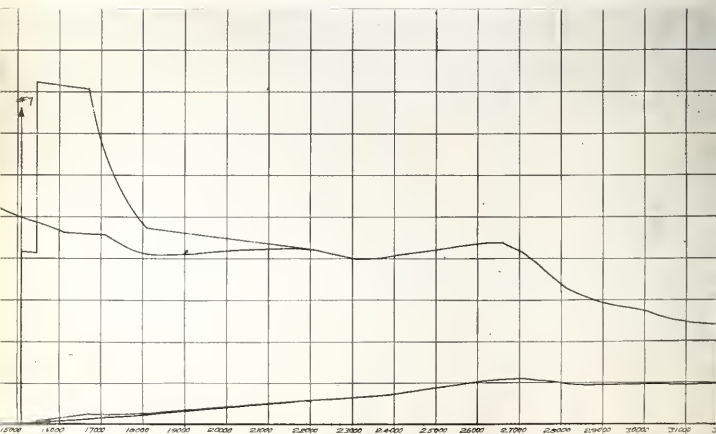
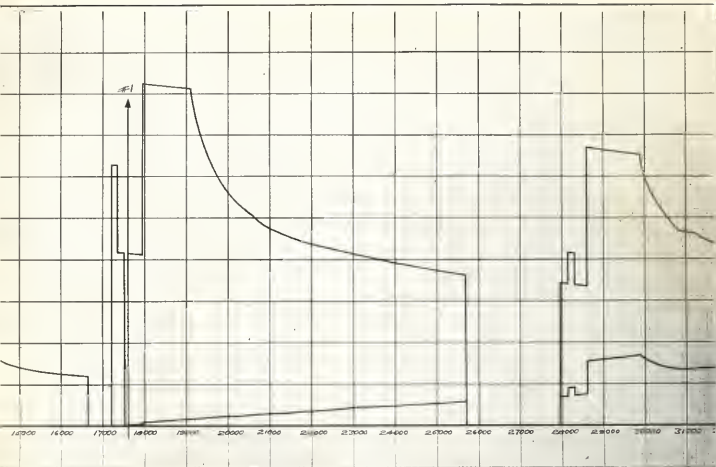


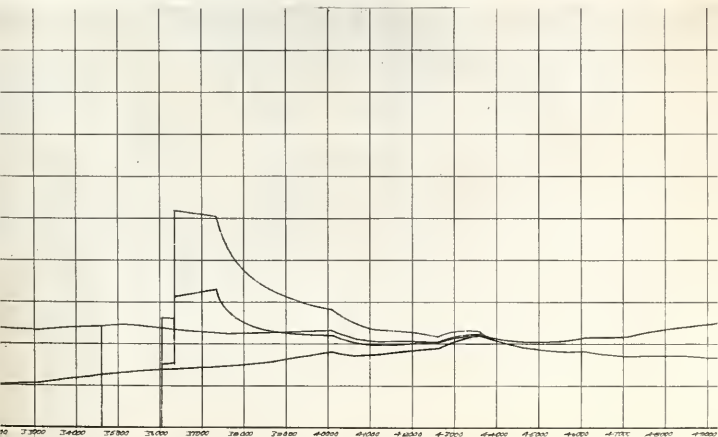
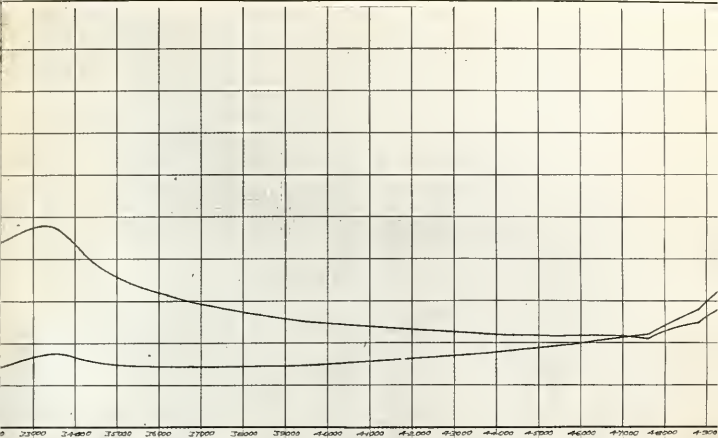


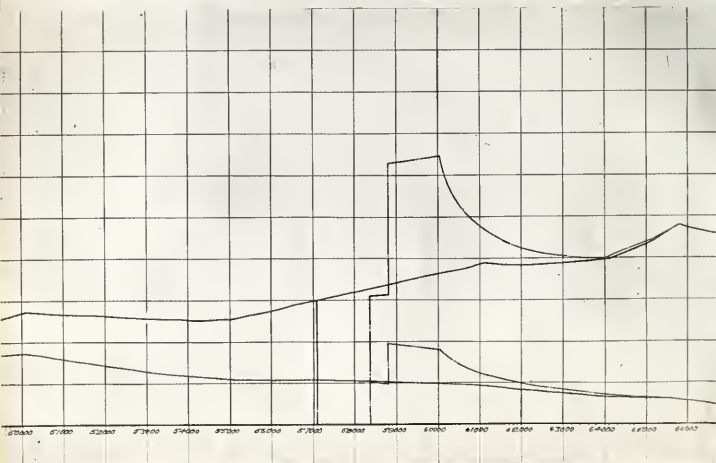
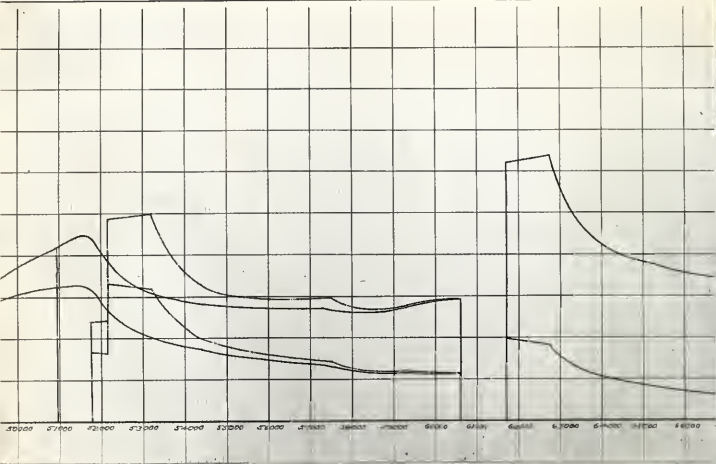


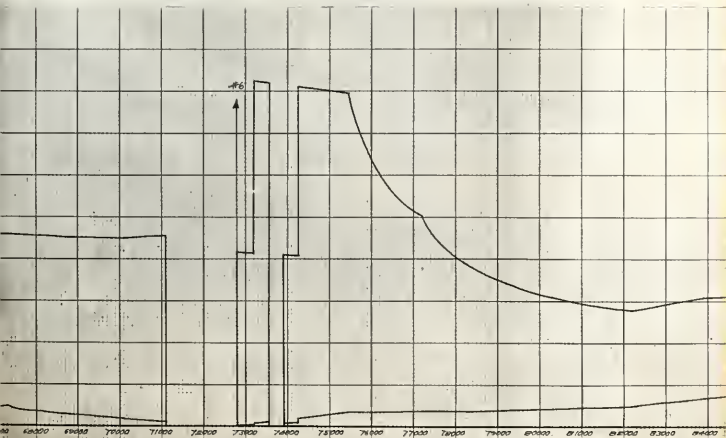
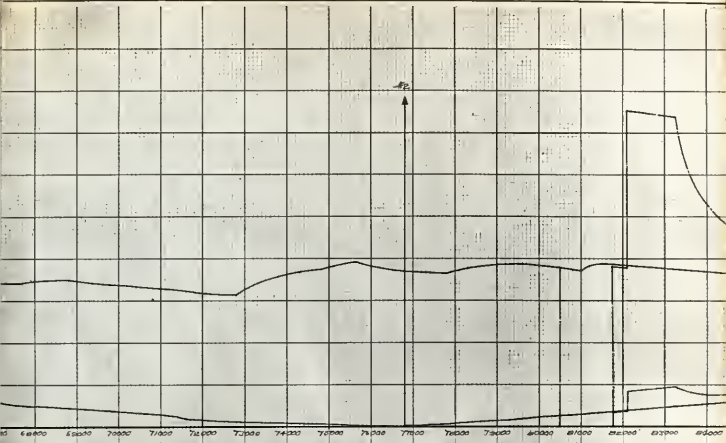
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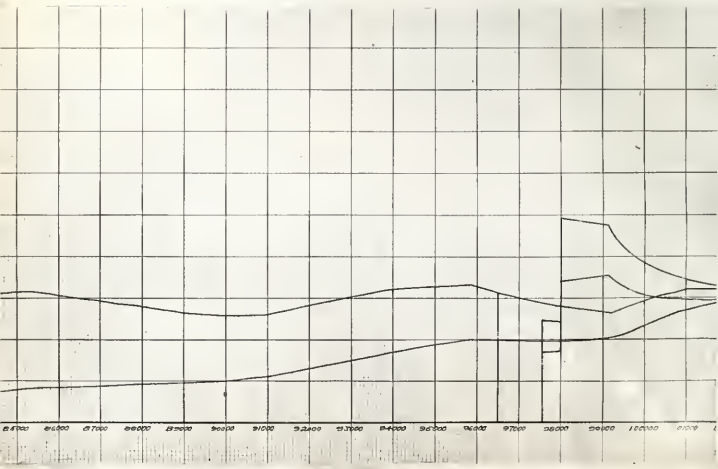
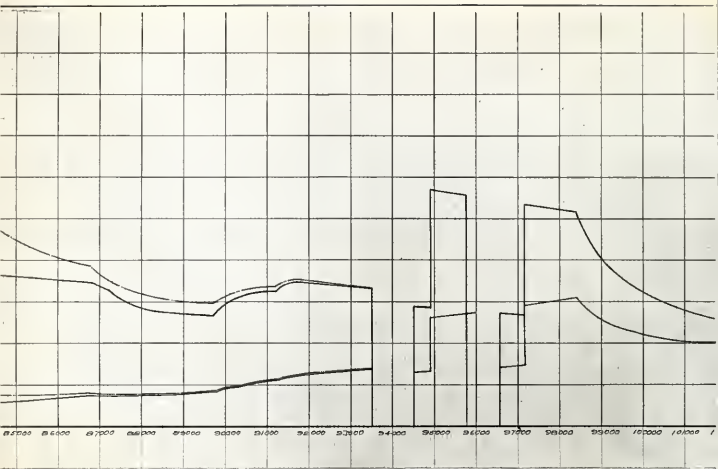


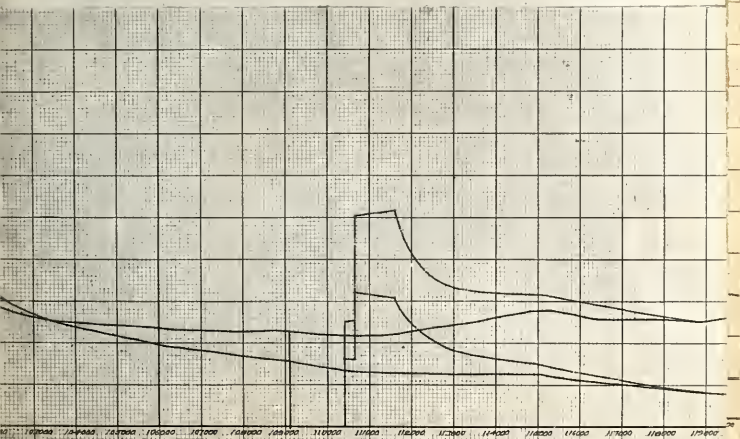
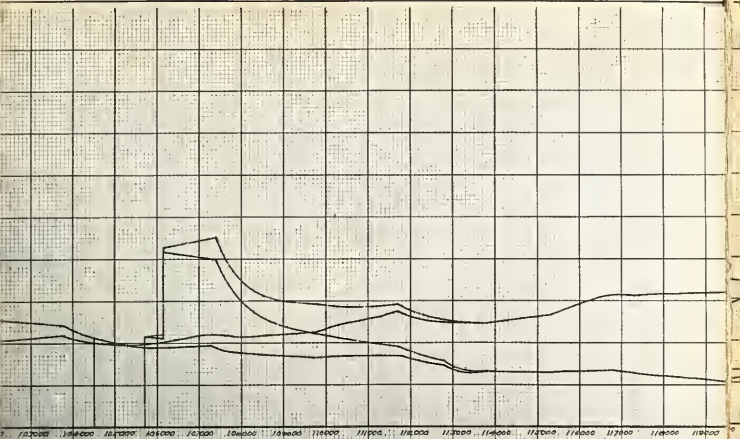


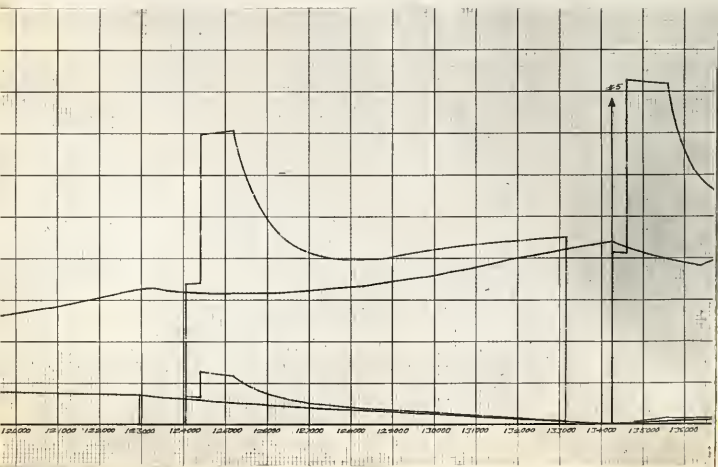
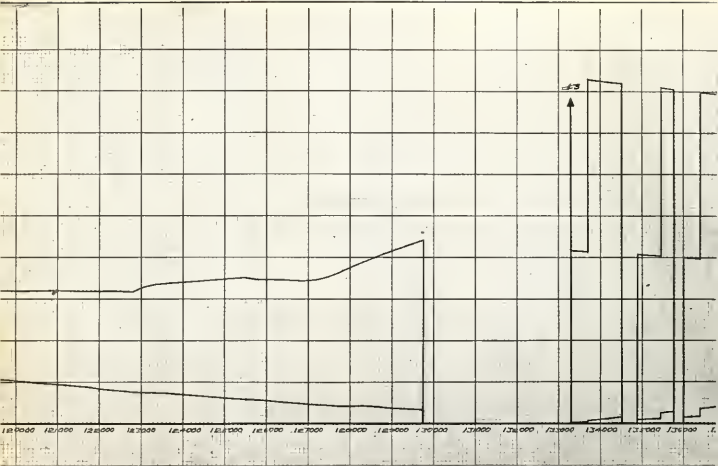


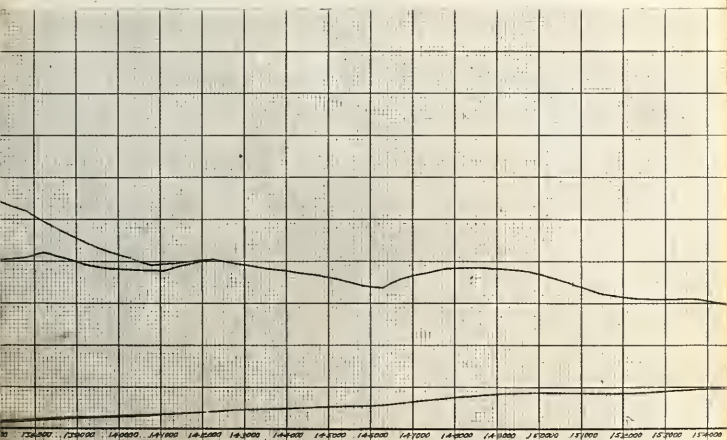
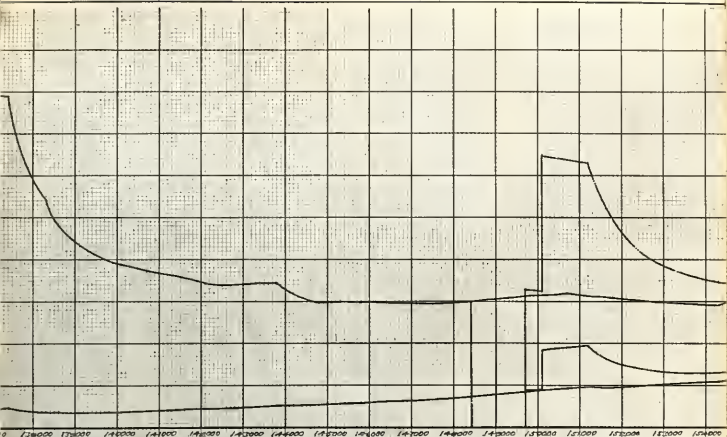


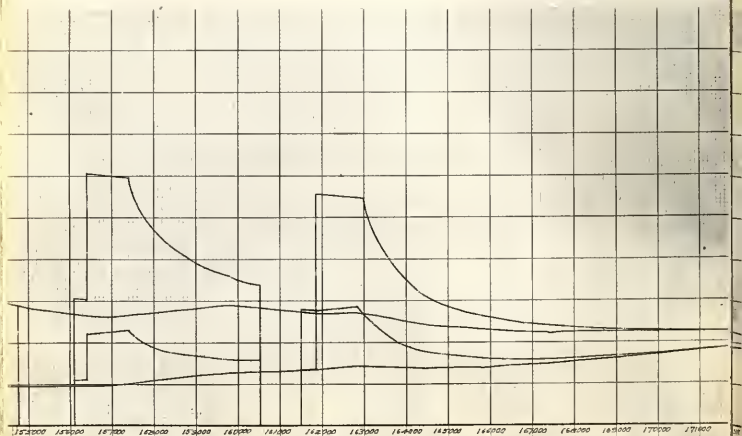
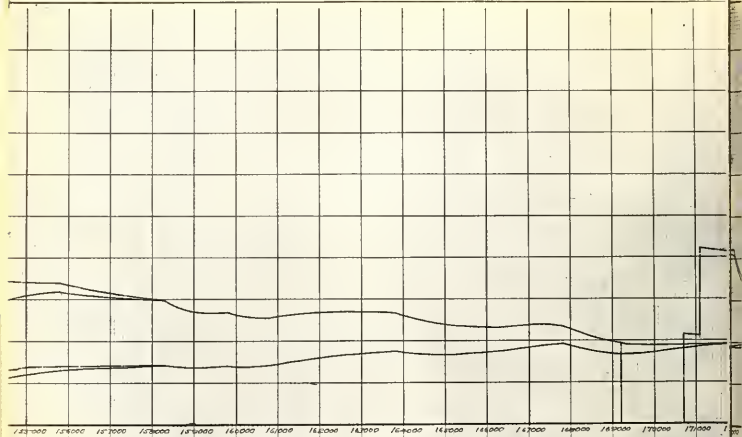


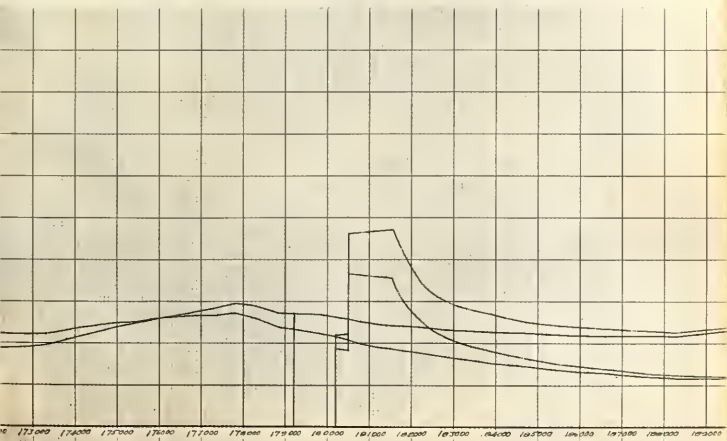
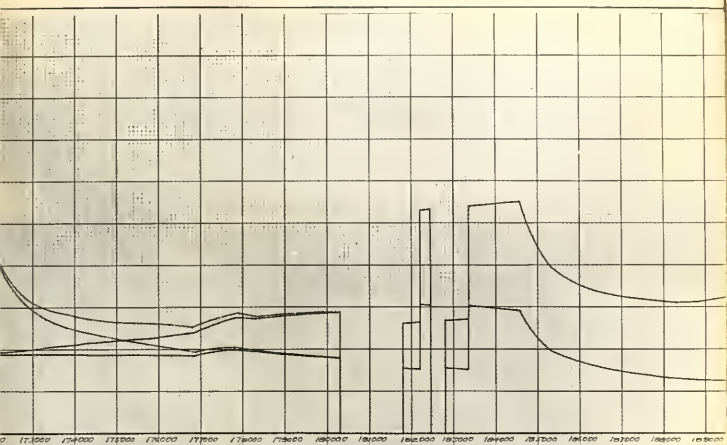


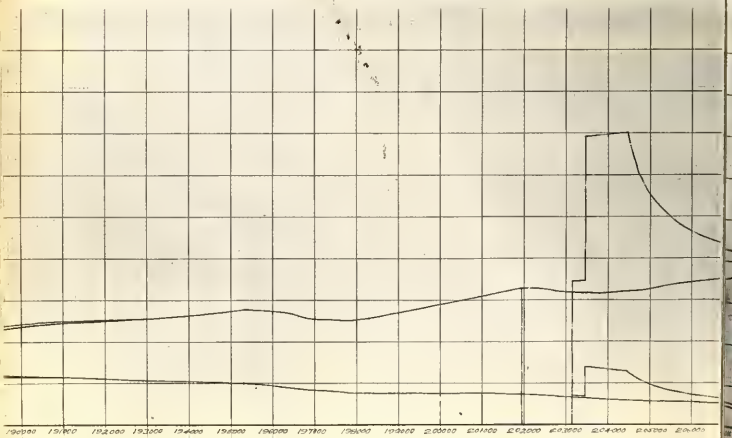
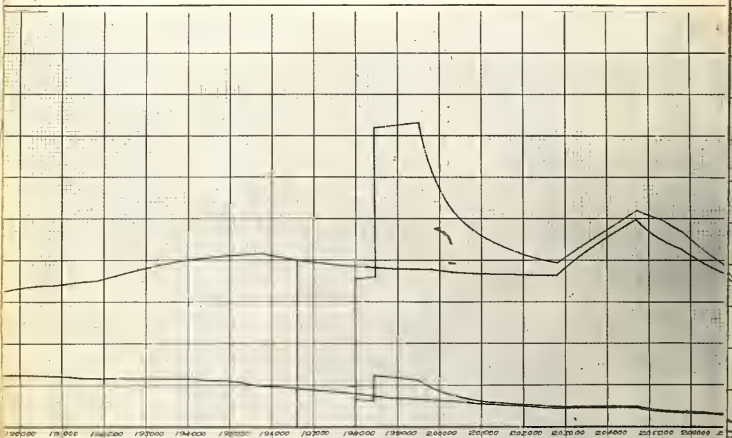


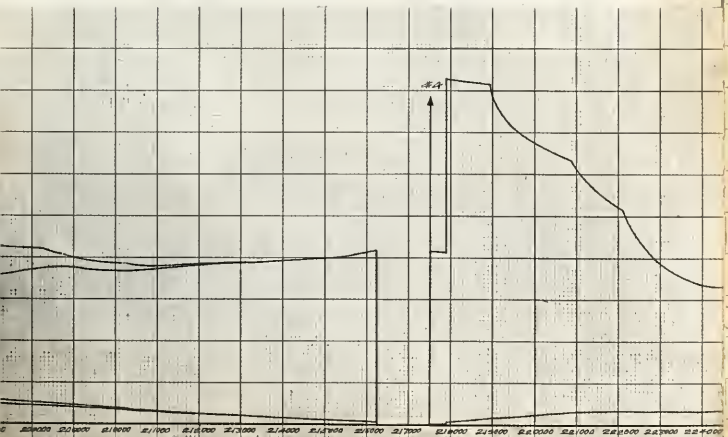
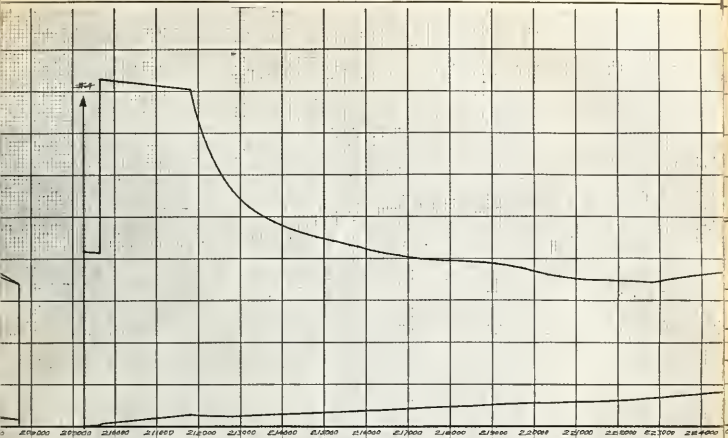


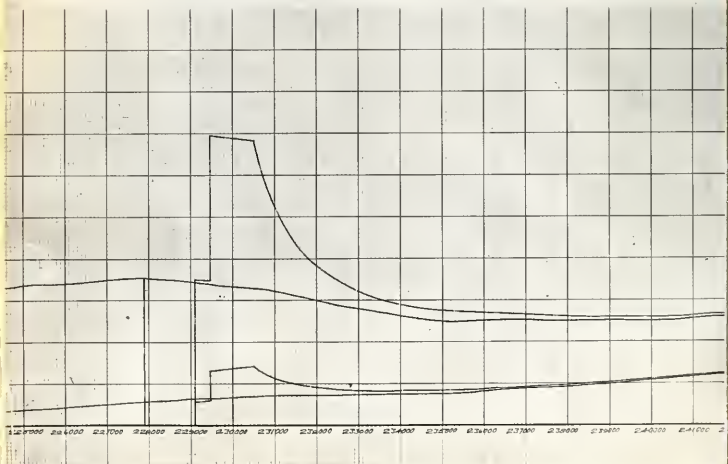
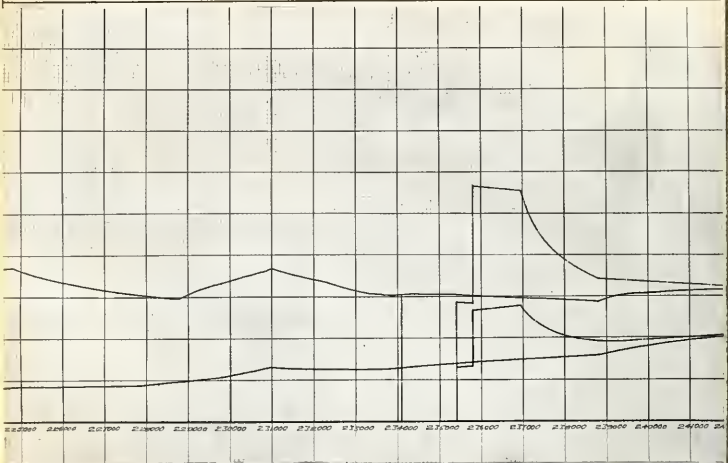


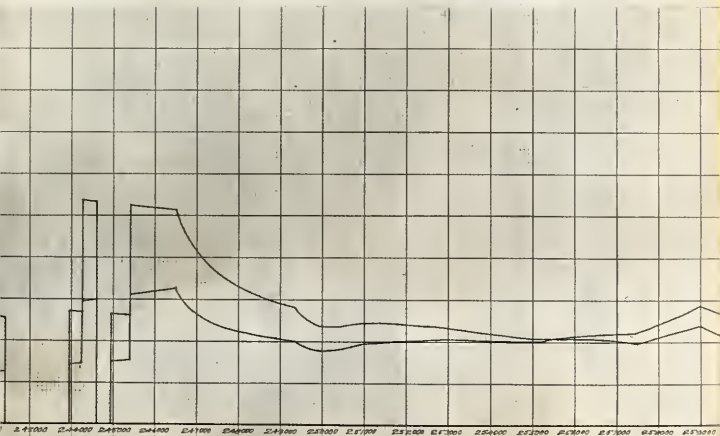
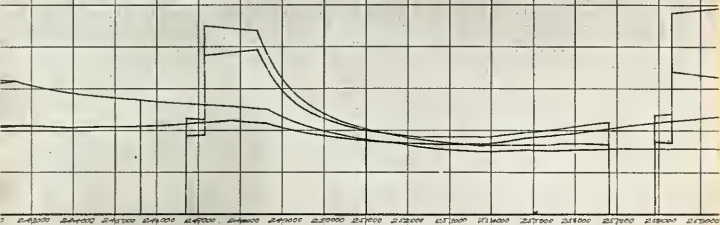


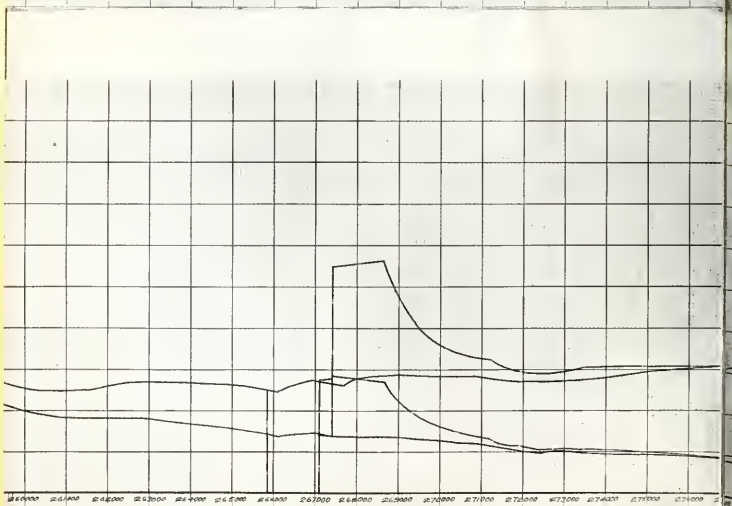
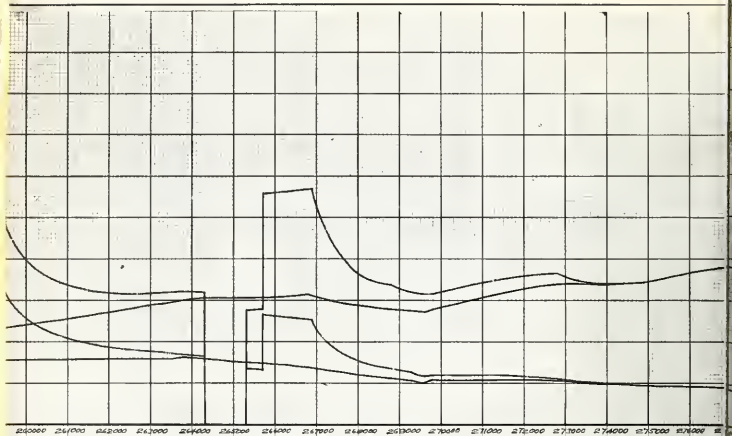


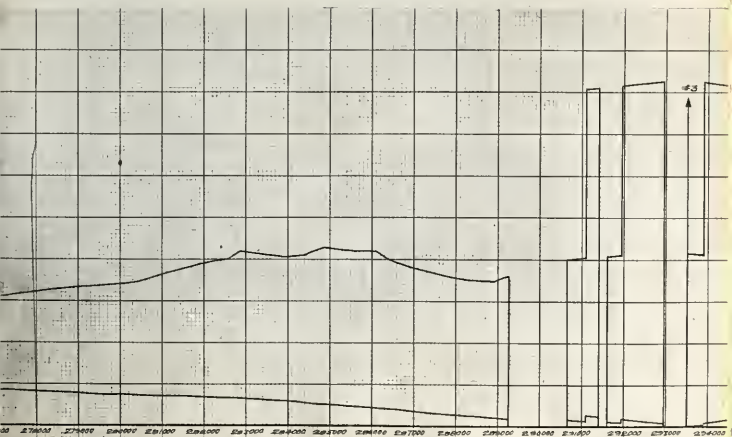
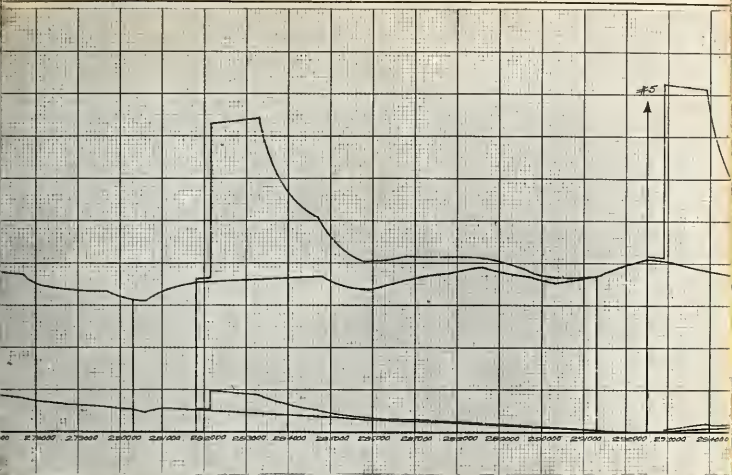


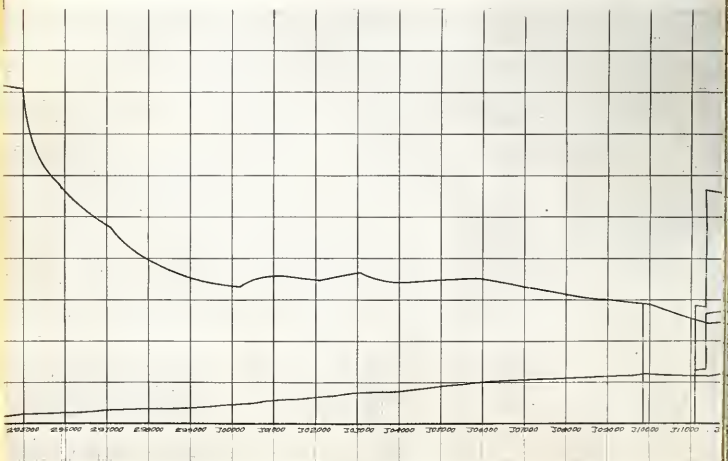
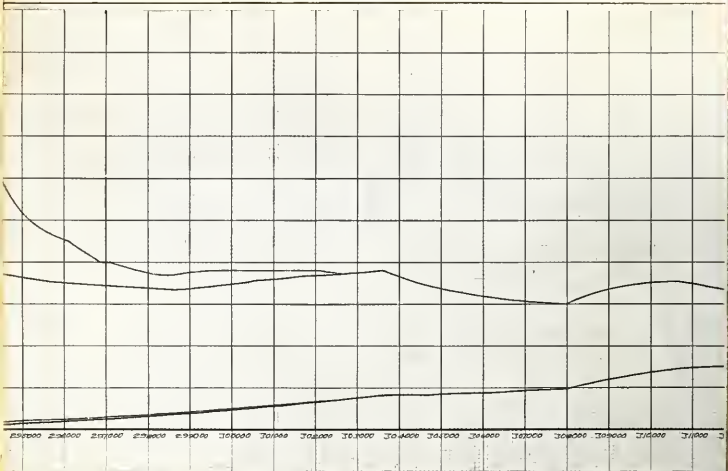


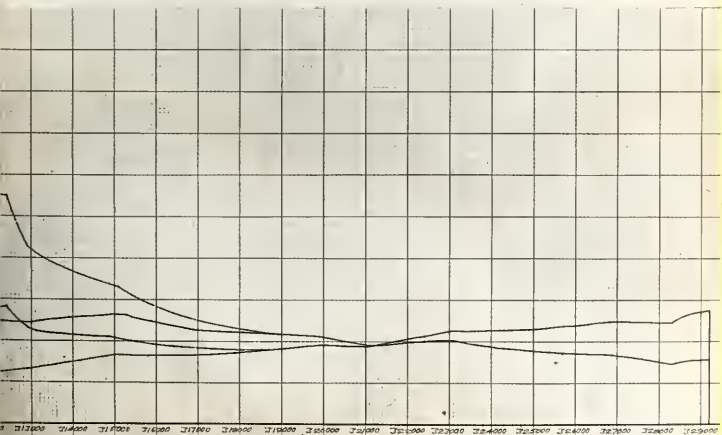
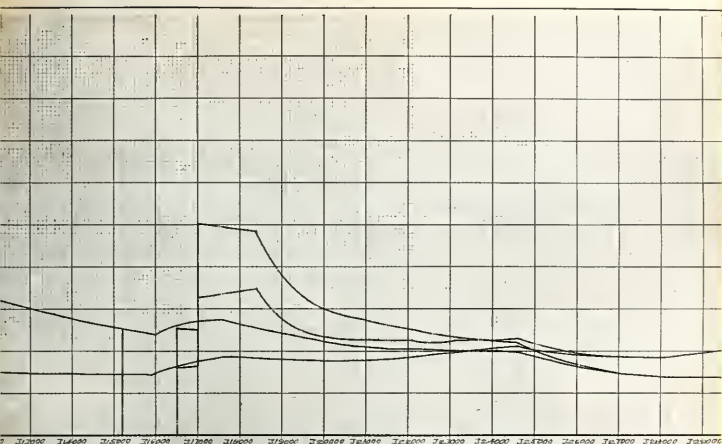


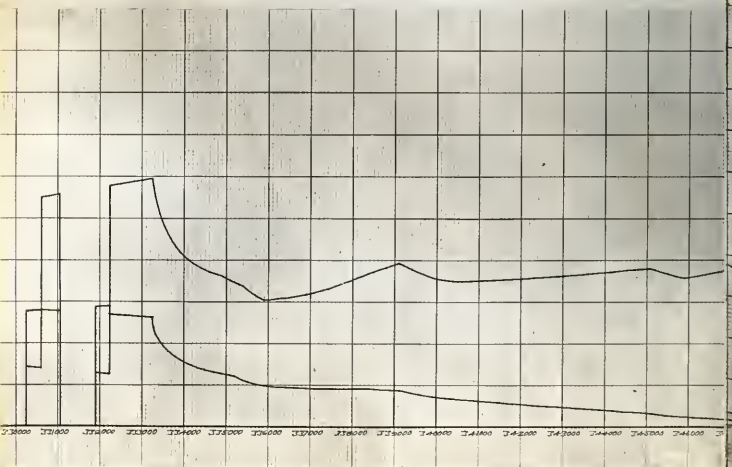
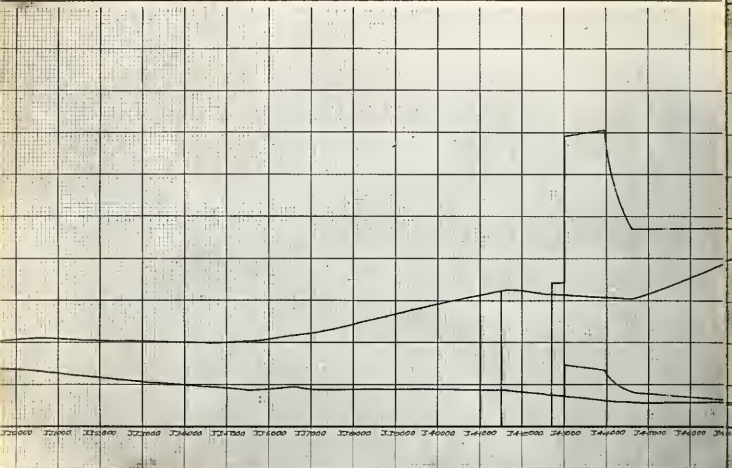


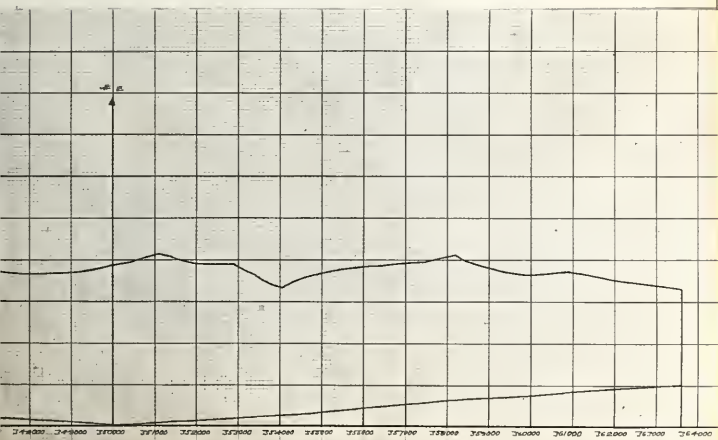
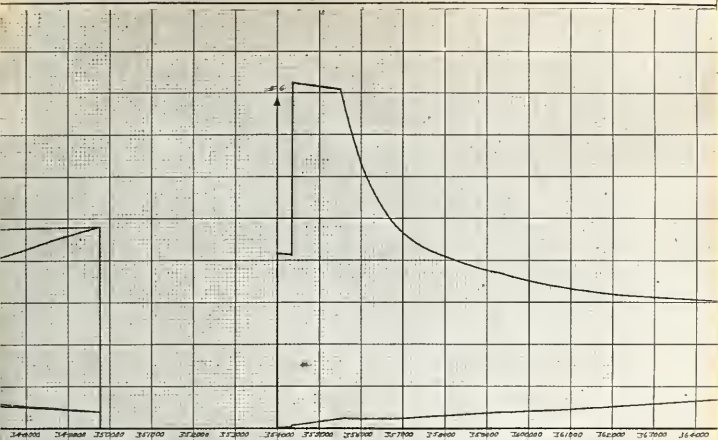


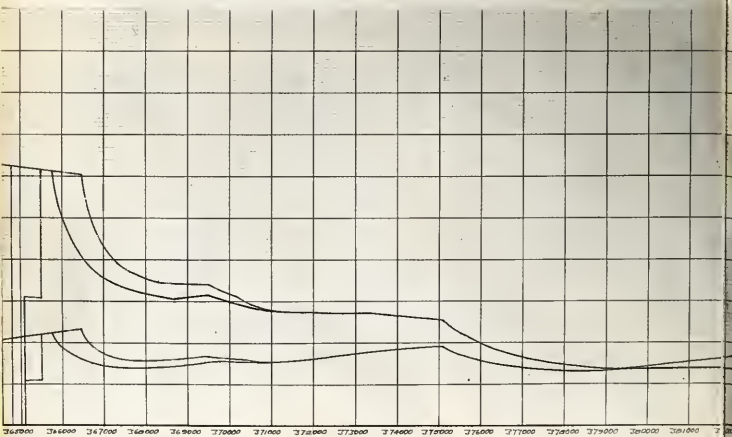
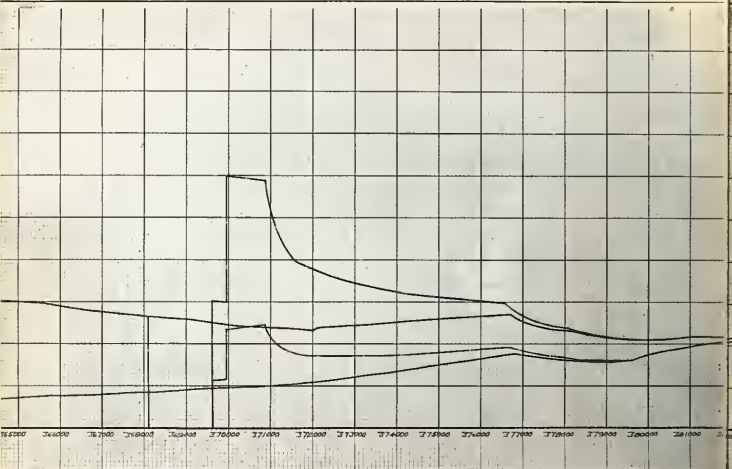


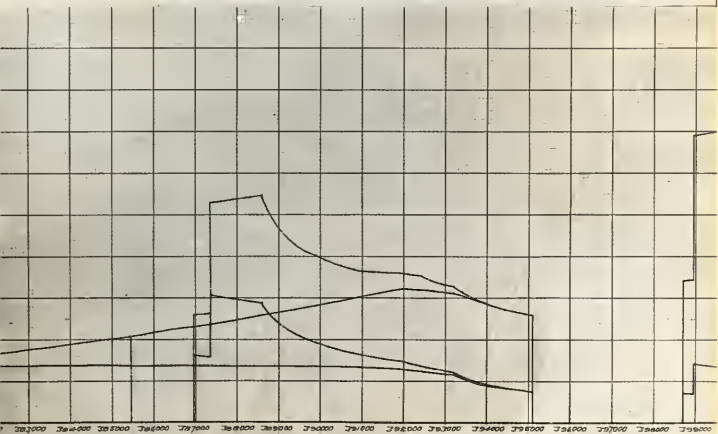
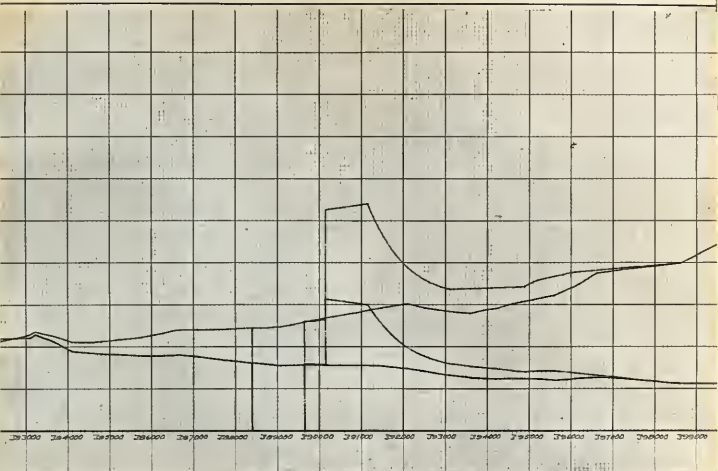


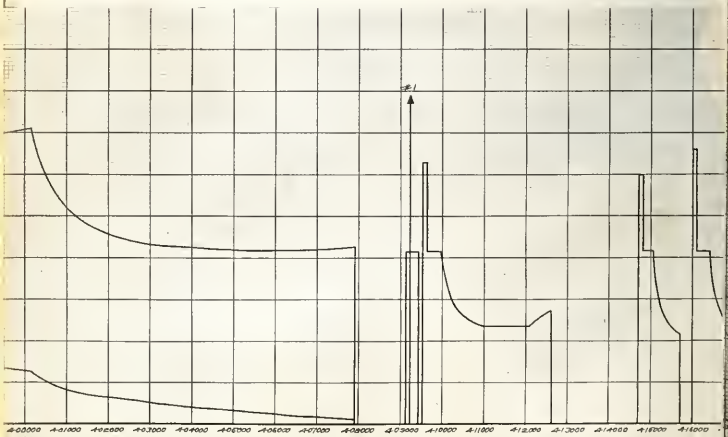
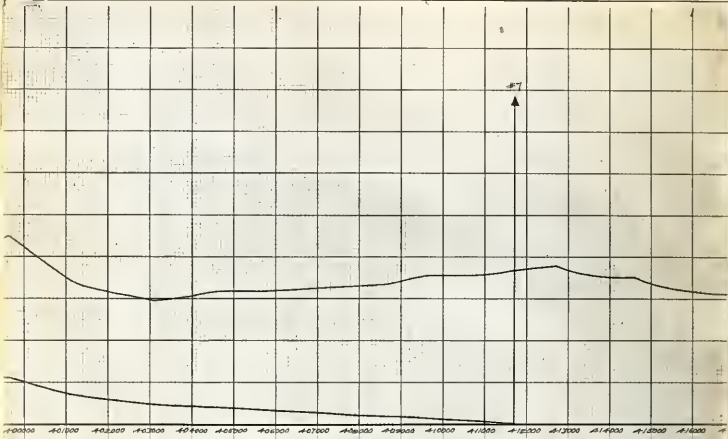


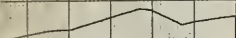




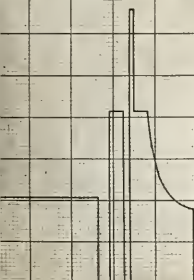








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